PROVE IT YOURSELF

Easy Experiments in Elementary Science

To my friends

Bob and Johnny

With best wishes

Bertha F. Gordon

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PROVE IT YOURSELF

A Book of Easy Experiments in Elementary Science

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With 88 Illustrations

F. A. OWEN PUBLISHING COMPANY
DANSVILLE, N. Y.

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Prove It Yourself

PRINTED IN THE UNITED STATES OF AMERICA

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INTRODUCTION

What makes the cover of a kettle move up and down?

When you pull a nail from its hole why is it hot?

How does a bell ring?

Why does a magnet point to one of the poles?

What becomes of the sugar you put in a cup of coffee? Is it possible to get it back?

When a man is pounding at a distance from you, why do you see the blow before you hear the noise?

How is it that a lump of coal and a diamond are first cousins?

When you put vinegar on an egg shell why does it froth and bubble?

How did pirates make their secret writing?

What is the hottest part of a flame?

Why are the kangaroo's front legs so short?

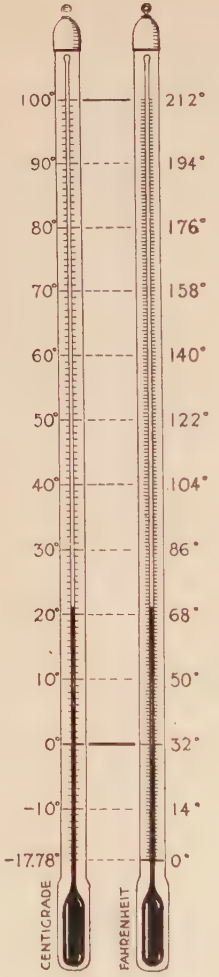
If you want to know the answers to these questions, and how to prove some of them by things which you can make yourself, read this book. The questions and answers and devices belong to a section of knowledge called Science. There are different kinds of sciences, such as Electricity, Chemistry, Astronomy, Light, Sound, Zoology, etc. It is easier to understand a big subject if we divide it into smaller parts, and take one part at a time. That is what we shall do in this book.

PROVE IT YOURSELF

HEAT

MOST heat comes to us from the sun. When we burn coal we are using heat that came from the sun long ago, and was stored up in plants. To measure heat intensity (hotness, or temperature), we use a thermometer, a glass tube closed at both ends. It has no air in it, but is partly filled with quicksilver (mercury). When the temperature around the thermometer increases, the column of quicksilver becomes longer. When it decreases, the column becomes shorter. The thermometer was invented by a man named Fahrenheit. On his thermometer, the freezing of water takes place at 32 degrees, and boiling, at sea level, at 212 degrees. Other substances freeze or boil at different temperatures.

The French people have developed another kind of thermometer called Centigrade, because it has one hundred steps, or grades, between the freezing and the boiling point. The melting point of any substance is the reading of the thermometer at the moment when the substance changes from a solid to a liquid. The boiling point is the reading when a substance begins to boil, changing from a liquid to gas.



The thermometers used in different countries are exactly alike in the construction of the tube but differ in the way they are marked.

The two thermometer scales in most general use are the Fahrenheit and the Centigrade. On the Fahrenheit thermometer the freezing point of water is at 32 degrees above the zero of its scale and the boiling point is at 212 degrees above. On the Centigrade scale the freezing point is marked zero and the boiling point 100.

To change readings on the Centigrade scale to the Fahrenheit scale multiply by $\frac{9}{5}$ and add 32. To change Fahrenheit reading to Centigrade subtract 32 and multiply by $\frac{5}{9}$.

FIGURE 1. Comparison of the Fahrenheit and Centigrade thermometers.

Radiation

We do not get much heat *directly* from the sun. Most of the sun-rays are either reflected or absorbed by materials on the earth's surface. Part of the absorbed rays may be thrown out again as heat. This throwing out is called radiation. Some substances absorb and radiate better than others. Things that absorb well also radiate well. The color affects this absorption of rays. Fill two ordinary drinking glasses of the same size with water at the same temperature. To get the water of the same temperature put in a large pitcher more water than needed to fill the glasses, and after stirring it a moment fill the glasses.

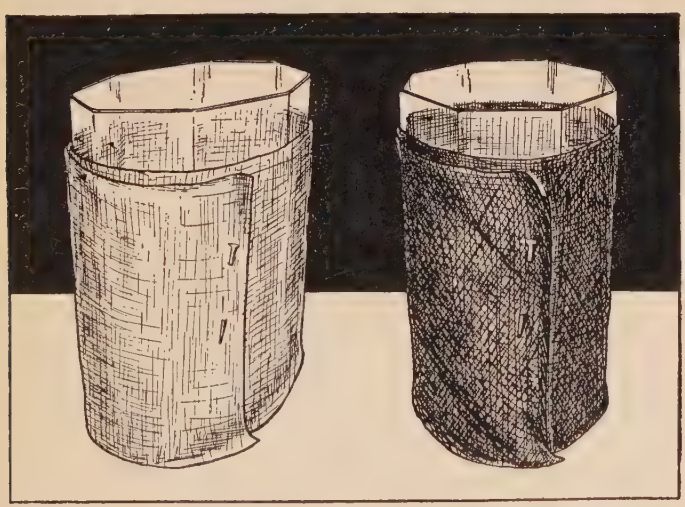


FIGURE 2. Experiment to prove that the color of a substance makes a difference in the absorption of heat.

from it. Around one glass wind white cloth, and around the other wind black, as shown in Figure 2.

After you have done this, set the two glasses in the sun for ten minutes. At the end of that time place a thermometer in the white glass and write down the reading of the scale. Then place the thermometer in the black glass and take the reading. You will find the water in the black glass about eight degrees warmer than that in the white. This shows that light colors throw off more heat than do dark ones, and thus explains why we wear dark-colored clothes in winter and light-colored ones in summer. It also explains why people living in hot countries wear white.

In almost every household there is a thermometer, and your mother will probably not object to your using hers in this experiment if you handle it carefully and wipe it dry when you are through with it; but it is better to have a thermometer of your own. One called a "dairy thermometer" can be bought at many hardware stores for about fifteen cents. In some cheap thermometers colored alcohol is used instead of mercury, but these instruments are not so reliable as those with mercury.

Conduction

As water flows in pipes, or as electricity flows through a wire, so heat will move along through a substance. This movement of heat is called conduction. By making a conduction machine, you can prove in a very interesting way just how this takes place. To do

this, you will need three lengths of wire of equal diameter, one length of iron, one of brass, and one of copper. The iron wire may be taken from an old broom. If you cannot find brass and copper wires the same size as the iron, you can buy little spools of such wire at hardware stores, for a few cents. Twist the three wires together at one end until the twisted part is about one and one-half inches long. Leave the other ends free.

Next, take two pieces of wood about five inches square and three quarters of an inch thick, and at the center of one bore a small hole into which the twisted ends will fit snugly. A grocer will give you an old orange box, from the ends of which you can saw out these squares. In the other square, bore three holes at least one and one quarter inches apart, all in the same straight horizontal line, so that the middle one of the three will be exactly opposite the hole in the first square. Push the twisted wire end into the center hole so that it will extend about one and one-half inches on the other side. Then bend the wires to separate them, and put one of each of the three ends through the holes of the second square, bending down enough wire on the other side so that none can slip back. The space between the two squares of wood should be about ten inches. The machine will work better if the blocks are nailed to a base of some sort—any large board may be used for this purpose. Leave room to set a candle or, better still, an alcohol lamp, under the twisted ends. This is your conduction ma-

chine. In order to work it you will need three exactly equal weights, say, three pennies.

Now fasten a penny to each of the wires with a little piece of shoemaker's wax the size of a medium-sized marble, so that the pennies are about midway between the two squares. Try to make it a fair test by fastening the pennies on the wires with an equal amount of wax to each. If the wax is too hard, it can be softened in an instant by holding it near a flame.

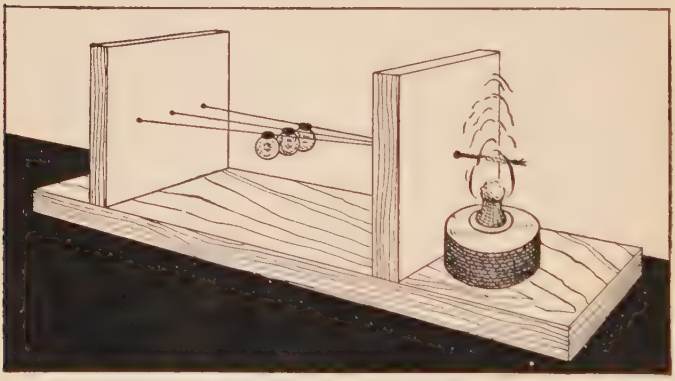


FIGURE 3. Conduction machine.

Light your candle or alcohol lamp and put it under the twisted ends. Anything flat, slipped under the candle, will raise it, if necessary, so that the wire will be in the hottest part of the flame—the upper third. Figure 3 shows you how such a conduction machine looks.

The square of wood prevents any direct heat from melting the wax. If any heat is to reach the wax, it

will have to go through the wires. Watch to see which kind of wire will drop its weight first. That kind will be the best conductor of heat. You will find that the weight will drop very soon from the copper wire. The weight on the brass wire will go next, a few minutes later. But the weight on the iron wire will remain for a long time; for of these three metals, iron is the poorest conductor of heat.

Expansion

All substances are made up of little particles called molecules. When heat goes into most substances it sets these particles in motion so that they push against each other and rush around trying to make more room for themselves. The substance then becomes bigger than it was before. In other words, it swells up. You can prove this by making an expansion machine. For this machine you will need a small iron rod. Bessemer rods are best. You can buy one at a hardware store, but the rib of an old umbrella may be used. Mount this rod in such a way that you can set your candle under the middle of it. One end of the rod must have something solid to press against; for instance, the end of a short wood screw. (See Figure 4.) The other end of the rod must press against some sort of lever so that the movement of the rod may be plainly shown as the heat makes it expand. The drawing shows the point of the lever directly under the point of the phonograph needle. This is their position when the rod is cool. The slightest expansion of the rod will push the

lever to the left and thus throw the points noticeably out of line. Further expansion of the rod will increase the space between the points.

A little paper dial with degrees of small size marked on it can be set up behind the lever and will show plainly the extent of the rod's movement. A piece of old clock spring may be used to push the lever back when the rod cools. Any jeweler will give you one for the asking. Take a good look at Figure 4 and make your machine as it is shown there. Set the candle under the rod and watch the lever move along from one degree to another on the dial. When the rod has expanded as much as it will, the lever will stop.

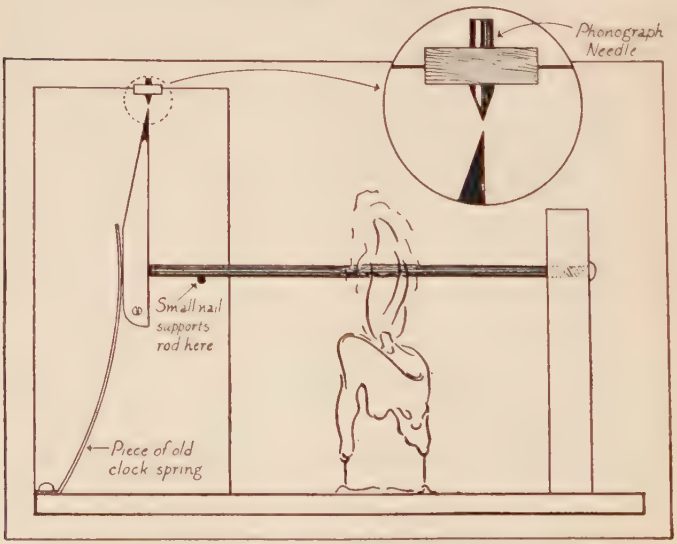


FIGURE 4. Expansion machine.

If you take away the flame, the rod will soon shrink again.

Nearly all metals shrink when they are cooled. An iron bridge shrinks in cold weather. One mile of telegraph wire is twenty-five inches longer in hot weather than in cold. Now, can you guess why a railroad is laid with little spaces between the ends of the rails? If you have ever seen a steel tire put on a wagon wheel, you will know how the wheelwright takes advantage of the fact that metal shrinks when cooled and swells when heated. He heats the tire and puts it on the wheel while it is hot. When it cools it shrinks and holds very tightly.

The frames of great iron bridges and of large buildings are held together by rivets which are hot when put in place. The shank of the rivet acts just like the metal bar on your expansion machine. It is expanded when set in place; and as it cools, it shrinks, and draws its two holding-ends together nearer and nearer. Now, you can tell exactly why the column of quicksilver in the thermometer is longer in warm weather; for quicksilver is a metal, even though it is in liquid form.

Boiling

Every child has seen the cover of a teakettle move up and down, and has heard the kettle "sing." But did you ever connect these two facts with the shrill sound that you sometimes hear when a piece of green wood is being burned? All are due to the same cause —steam. Light your alcohol stove (as shown in

FIGURE 5. When water is boiled it passes off in steam.

Figure 5), or a single burner on the gas stove. Place over it a tin cup or small pan into which you have put half a cup of cold water. In bringing the water to the boiling point you can find the answers to these questions:—

1. In which direction does the air move above the water?
   (To find this out, hold a strip of tissue paper four inches long and one-quarter wide above the boiling water.)

2. How many minutes pass before the first bubbles appear?
3. In what part of the water do they show first?
4. How long before the first thread of steam curls up?
5. How long before the whole mass of water is boiling?

Now empty out the hot water, and put in another half cupful. This time cover the water with a tin cover. Does the cover make any difference about the time of boiling? Empty again, and fill with a whole cupful of water. Does twice as much water take twice as long to boil? Look at the under side of the cover and notice the tiny drops clinging there. How did they get there, and why? The cover, being farther away from the flame, was cooler; and so the steam as it touched the cooler surface, condensed to form the little drops. They did not splash there in the boiling. Mix a spoonful of salt with half a cup of cold water, and see if it boils more quickly than the fresh water.

The Steam Engine

Steam is like the rod in your expansion machine—heat expands it. It was expanding steam that lifted the cover of the teakettle. A locomotive is really a big teakettle on wheels. A very hot fire quickly boils the water; the steam passes into the steam dome and through a pipe to the steam chest, and then into the cylinder, which contains the piston. First the steam comes in behind the plate of the piston and drives it

over to the other end of the chest. Then the first steam is let out and new steam, let in in front of the plate, drives the piston back again. The back-and-forth motion of the piston is changed into the round-and-round motion of the wheels by the connecting rod. It is great fun to make a little working model of a steam locomotive, showing the steam chest cut open so that the inside of it can be seen. In the steam engine, it is the vapor of water (steam) which does the work.

Annealing

If you are to do real annealing, you will need two pairs of pliers, or "pinchers," as they are often called. Take an ordinary sewing needle in two pairs of pliers and break it. (The pliers should be held in line with the needle, one pair at each end.) You will see that it snaps in two quite easily. Now take another needle and heat it in a flame until it is red-hot then allow it to cool slowly in the air. It will take about two minutes for it to cool. Try to break this needle with the two pliers as you did the other. You will find now that it only bends, and does not break at all. Your experiment has proved that the needle was softened by the heating. This softening of metal by heat is called annealing.

The hardness of steel makes it possible to grind a sharp point on a needle, or a keen edge on a chisel, plane blade, or knife. But hard steel, as we have just proved, is also very brittle, so that a hard piece of steel would not make a good screw driver. Steel for screw

drivers is softer. A chisel, wrongly used as a screw driver, is sure to break on the edge.

Can the brittleness be put back into the needle? Let us see. Bend the second needle out straight again, and heat it red-hot. Then plunge it quickly into cold water. Test for brittleness, and you will find that it is brittle.

How does the toolmaker tell whether his steel is the proper hardness for screw drivers or chisels and how does he get this hardness? He heats the steel white hot and plunges it into water or oil, getting extreme hardness as you did with the needle. He then partially anneals it by reheating to a comparatively low temperature. This partial annealing is called tempering. The less the steel is tempered, that is, the lower the temperature of the reheating, the harder it will be left. As the piece is reheated, surface colors appear. When the color indicating the desired temper is reached, the steel is again suddenly cooled. The following are the temperatures at which the colors appear as steel is reheated. The hardest steels are at the top.

1. 450 F. Straw color (for razor blades)
2. 490 F. Brown (for shears, scissors)
3. 530 F. Purple (for chisels, plane blades)
4. 570 F. Blue (for swords, springs)
5. 600 F. Dark blue (screw drivers)

The temper of a knife may be ruined by using a dry grindstone. The heat of friction completes the annealing and leaves the blade soft. Keeping the grindstone wet cools the blade and saves its temper.

Friction

Friction—the rubbing of surfaces together—causes heat. Every Boy Scout knows that by rubbing sticks together briskly sufficient heat can be produced to start a fire. This was the method used by the Indians in starting a fire. Drive a nail into wood and pull it out quickly. Is it hot? Rub your hands together hard for several seconds and then hold them against your face. Do they feel warm? Now you can answer all of these questions:—

1. Why do sparks fly when the horse's shoe strikes a stone?
2. What makes a scroll saw get so hot?
3. What causes a "hot-box" on a train?
4. Why is it dangerous to slide fast down a rope?

There are other things besides friction that cause heat. One of them is pressure, but it takes so much pressure to make even a little heat, that you will have to take the word of scientists for this fact, since you cannot prove it yourself. The combining of some chemicals causes heat, as you will see later. A substance cannot change from a solid into a liquid, or from a liquid into a gas, without taking up heat.

Now that you have come this far in your science experiments, you have, of course, found that you have a great many things to remember. It would be a good idea to get a small notebook and write down some of them. This notebook will be handy, for sketches and drawings that you will want to make. In science work you will meet many new words; some of them are

Every Boy Scout knows that by rubbing sticks together briskly sufficient heat can be produced to start a fire.

hard to remember, and some are long. It would be well to keep a list of these words in the back of your note-book, and once in a while, write out the hardest ones on a slip of paper. This will help you to learn to spell the words, and also to remember them. At the end of some of the subjects in this book you will find a list of such words, and you can copy them into your book. Are you going to be "a good sport" and learn these big words, or are you going to be the sort of person an Indian would call "Young-Person-Afraid-of-a-Big Word"?

List of Words

thermometer	radiate	chisel	brittle
quicksilver	radiator	expansion	plane-blade
mercury	radiation	screw driver	tempering
tube	temperature	steam	grindstone
column	conduction	anneal	friction
Fahrenheit	alcohol	annealing	blacksmith
degree	molecule	annealed	horseshoe
reflection	forge	pliers	pressure

DISSOLVING AND EVAPORATING

TAKE three pieces of paper, each about five by five inches. Mark one piece "sugar" and on it place five level teaspoonfuls of sugar. Mark another piece "salt" and on it place five level teaspoonfuls of salt. Mark the third piece "chalk" and on it place five level teaspoonfuls of chalk. (You can make chalk powder by crushing a stick of chalk with a heavy weight.) Beside each of these papers place a spoon, and an ordinary drinking glass a quarter full of water.

Put the sugar into the glass beside it and stir for three minutes. Put the salt into the glass beside it and stir for three minutes. Do the same with the chalk. The sugar will all dissolve and the salt partly, but the chalk will not appear to have dissolved at all.

Now add enough water to fill the glasses and stir the salt and chalk each for three minutes. The salt will have dissolved completely now, but the chalk will still be at the bottom of the glass.

We conclude from this experiment that sugar is the most soluble of these three substances, and chalk the least soluble.

How is melting different from dissolving? What has become of the salt? Could we get it back again?

Ask your mother to lend you a big iron spoon. Light a candle or a burner on the gas stove and hold this

FIGURE 6. Experiment in evaporation.

spoon half full of the salt water over the flame, as shown in Figure 6. It quickly boils and little clouds of steam go up. As it continues to boil the quantity of water gradually grows less and less. Finally the water has all changed to steam, and the bottom of the spoon is covered with a white crust of salt. If you were to keep on doing this until all the water had passed off in steam you would have all the salt back again. You could get the sugar back again, too; but sugar burns so easily that you could not help scorching it in boiling away the water. This would fill the house with a disagreeable smell; so do not try that. While the steam

is going up from the salt water, hold a cool spoon over it till a little has condensed on this spoon. Then taste it to see if any salt has gone off in the steam.

Driving off the water in this way is called evaporation. Into a shallow pan and a tall pickle bottle put exactly the same amount of water. Let them stand for several days. Then measure the water that is left in each one. You will find that there is much less water in the shallow pan than in the bottle. This is because there was more water exposed to the air in the pan than in the bottle.

How does fanning cool us in hot weather? Why do clothes dry more quickly on a windy day than on a still day? Here is another "race" that you can run all by yourself. With a medicine dropper put three drops of water on one side of the bottom of a small plate. On the opposite side put three drops of alcohol. Now fan the drops gently (not hard enough to move them) and see which disappears first. Alcohol wins the race. Now you can understand why a nurse gives an alcohol rub to a person with a fever. Its rapid evaporation requires heat, which is taken from the body, giving a cooling sensation.

Whenever water changes into vapor (evaporates) it must use up heat in order to do so; and therefore it must leave the space around it cooler than before. One of the reasons why it is cooler under the trees in hot weather is because there is always a great deal of evaporation going on from the pores of the leaves.

DISTILLATION

YOU have seen the drops of water collect on the under side of the lid of a pot when something in the pot is being boiled. You have also noticed that if the teakettle boils for a while, the steam condenses on things in the room, especially on the windowpanes, leaving them covered with drops of water. This change from liquid to gas and back to liquid is called distillation. Ordinarily we condense the gas on the inside of a pipe down which the resulting liquid can run into whatever container we desire. Since the wall on which the vapor condenses must be relatively cool, we cool this pipe, say, by running water over the outside.

Liquid

If we have a mixture of several substances which boil at different temperatures and we heat a mixture of them, the one with the lowest boiling point will vaporize first. If we condense this, collect it and then heat the mixture some more, the next thing will boil out. Petroleum is separated in this way. The first portion or "fraction" which boils out is called petroleum ether; then come in turn, gasoline, kerosene, and lubricating oils. Vaseline and paraffin are obtained from the "fraction" which does not distill. Because the mixture is separated into fractions which boil at

different temperatures the process is called fractional distillation.

Destructive Distillation

When some things are heated, instead of melting or boiling, they are broken apart by the heat to give new substances. If you try to boil pure sugar, it will do this. Your mother would say it "burned." Pie crust, cake, meat, and the like break up without ever melting. If we break up a substance by heating it and then condense the gases that come off just as we collected water from steam, the process is called "destructive" distillation, because the original substance is destroyed.

Coal is destructively distilled in this way to give illuminating gas. You can put some coal dust in the bowl of a clay pipe and close it with a tightly fitting cork. Heat the pipe bowl, and gas will come out through the stem and may be lit just as you light a gas burner.

FERMENTATION

IN any living thing, food is being used up and various products formed. Some of these products are injurious and are thrown off. There is a tiny plant called yeast, too small to be seen without a microscope, which eats sugar. The products formed and thrown off are alcohol and carbon dioxide, a gas. When the yeast has lived in a mixture containing sugar and has made some alcohol and carbon dioxide, we say that the mixture has fermented. Your mother would say her preserves had "worked."

When yeast is mixed with bread dough it starts to produce the alcohol and carbon dioxide. The carbon dioxide, being a gas, makes bubbles in the dough that become open spaces in the bread when it is baked.

As long as yeast is kept cool, nothing happens. That is why the dough is set in a warm place to rise.

List of Words for Dissolving, Evaporation, Distillation, and Fermentation

dissolving	crude oil	sugar	evaporate
quality	vaseline	vapor	gasoline
combined	salt	ether	yeast
benzine	chalk	lubricating	amount
dissolve	distillation	measure	naphtha
quantities	paraffin	process	dough

MAGNETISM

YOU will need a pair of bar magnets for these experiments, and although it is always easy to secure horseshoe magnets, you may not find it so easy to get them in the bar form. Some hardware stores and the toy departments of some department stores sell them. You can surely get them from firms in the larger cities handling scientific supplies. They are from twenty-five cents to fifty cents a pair, according to size.

Scientists say that there is a wonderful and mysterious force in the magnet called attraction. What will the magnet attract? Try pieces of glass, paper, wood, zinc, aluminum, tin, copper, brass, and different kinds of coins. Write down the result in your notebook. Now try the magnet on a needle, and on a nail. You see that its attraction is strongest for iron and steel. Try touching the nail-head with the middle of the bar magnet instead of with the end. You have proved that the magnet attracts at its ends, or poles, as they are called, and not at its middle, or equator. Now tie a thin string tightly around the middle of one of the bars and let it hang so that it can swing about freely. Leave it alone until it stops swinging and then notice how it hangs. It will point north and south. Now turn it east and west and let go of the string. It will

swing around for a while, but when it comes to rest it will again point north and south. This is because the earth itself is a big magnet with poles and an equator, and our little magnet feels the force of it.

You will enjoy experimenting with your bar magnets much more if you have a magnet stand. Any sort of thick soft wood may be used to make one. Cut out a base eight or ten inches square and nail an upright stick a foot or so long to one edge of it. Nail another stick about eight inches long to the top of the first stick so that it is parallel to the base. In the end of this stick drive a small nail on which to hang the string that you have tied around one of the bars. The whole stand will be stronger and endure more wear if you screw the sticks in place instead of using nails. (See Figure 7.)

Hang up one bar on your magnet stand and bring near one of its ends, first the north pole and then the south pole of the other bar. The poles are marked *N* and *S* on the tips of the bars. By this experiment you have proved one of the important laws of magnetism; namely, that different poles attract each other, and the same poles repel each other. That is, *N* on bar number one will turn away from *N* on bar number two; but it will follow after *S* on bar number two.

The force of the magnet works through the air around it as well as through the magnet itself. Prove this by moving a bar around under a paper on top of which you have laid a needle. The needle will follow after the bar wherever it goes, although there is an air

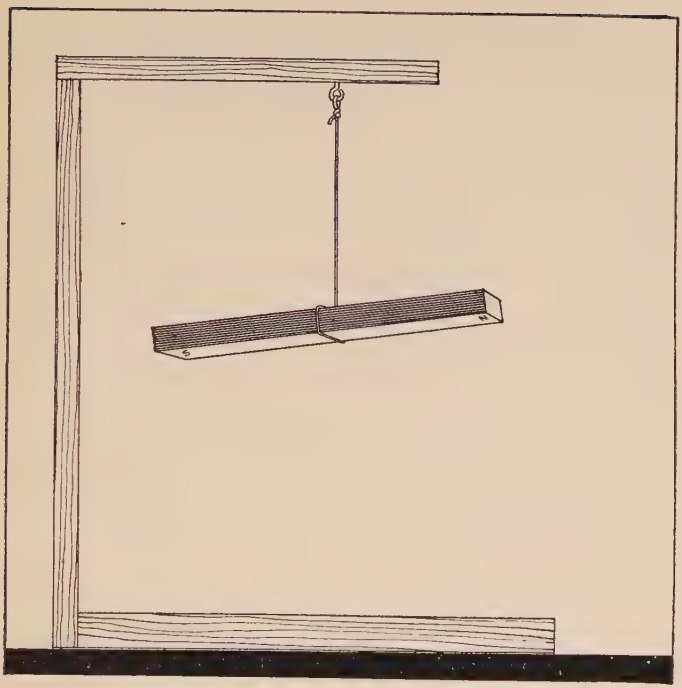


FIGURE 7. Magnet stand, with bar magnet.

space and sheet of paper between them. The space in which a magnet exerts force is called the magnetic field.

A piece of iron that touches a magnet, itself becomes a magnet. Hold a large nail with a big head against one of your bars, or fasten it on with a rubber band. Then dip it into a handful of small nails. You will see that the little nails cling to the big nail as if it were a magnet. But its magnetism is only borrowed.

Jerk the big nail away from the bar, and the little nails will fall off.

A piece of iron that comes near a magnet, without touching it, becomes magnetized. To prove this, cut a piece of wood about eight inches long, one inch wide, and three quarters of an inch thick. Drive a large nail

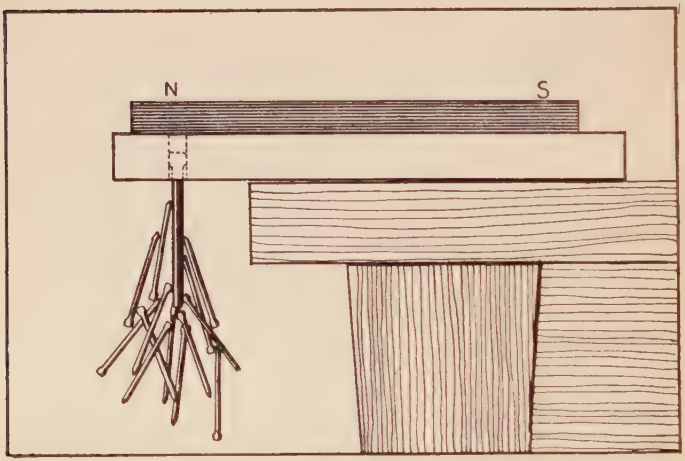


FIGURE 8. A piece of iron (the nail) influenced by a magnet but not touching it, becomes magnetized.

through one end of it, and sink the head of the nail deep into the wood. A nail with a small head will be less apt to split the wood than one with a large head. Now lay a bar magnet on top of the wood and fasten it on with two rubber bands. It should be near the nail, but not touching it. (See Figure 8.)

Dip the nail into some little nails, and you will see that the big nail is magnetized. But as before, if you

take the bar magnet away, the big nail loses its magnetism, and the little ones fall off. It may be that one or two will stick to the big nail. That is because the big nail does not lose all of its magnetism immediately.

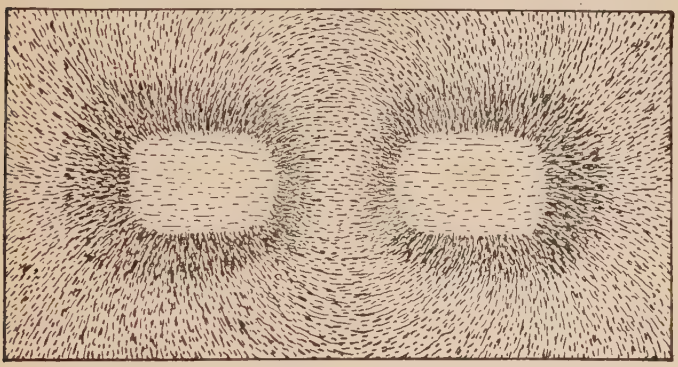


FIGURE 9. The iron filings arrange themselves along the lines of magnetic force.

The magnetism that remains in it is called *residual* magnetism. In a few moments even that leaves.

In the magnetic field the force of the magnet is directed along paths which are called lines of force. You can make the lines of force show themselves in a very striking way. Lay two books on the table about three inches apart, and put one of your bar magnets in the space. Lay over the books a sheet of stiff paper or thin cardboard. On the cardboard sprinkle a few pinches of fine iron filings, and tap the edge of it with a pencil. The filings will arrange themselves all along the lines of force, and make a perfect diagram of the direction in which they are flowing. (See Figure 9.)

Draw in your notebook a sketch of this diagram, marking the two poles, the equator, and the lines of force. You can make enough iron filings for yourself by filing up a nail or two, or any piece of old iron that is not too rusty. Or you can get some free from any machine shop. Machine shop filings, however, are apt to be covered with oil, and you will need to clean them. Put them in a bottle with a little gasoline and shake them well for several minutes, then pour them out on a newspaper to dry. (Keep the gasoline away from fire.) If you want to get them very fine and soft, sift them through a fine sieve. Keep them in a little jar or in a jelly glass having a cover.

There is a kind of natural rock, called lodestone, that has magnetism. The name magnet was given this rock because it was first found in a country called Magnesia. If you have ever read *Arabian Nights*, you will remember a story about a mountain made of lodestone. If any ship sailed near it, it was sure to be wrecked, for the mountain had such strong attraction that it drew all the nails out of the ship.

Will the magnet work through wood, or glass, or through your hand? You have already shown that it will work through cardboard or paper. Get a piece of a broken windowpane and sprinkle filings on the glass. Then rub the magnet around underneath it. The filings stand up like the hair on an angry dog's neck. It is the same with very thin wood. But the magnet will not work through a great thickness of wood. Hang one of your bars on the magnet stand, and ap-

proach it with one pole of the other bar, holding your hand between them. You will see that the lines of force flow through your flesh, too. Do you feel anything in your hand?

Prove that the big nail which lifted the little nails was only *magnetized,* and not a *magnet.* You will have to show that it has no poles, because it is not repelled by any pole of the hanging magnet.

You can put some of your iron filings into a glass and mix them with fine dry sand. Then you can "refine" the mixture—that is, get back your filings—by stirring it with one of your bar magnets and drawing it out covered with the filings. The sand is not attracted, and so remains in the glass. You will find it rather hard to scrape off the filings from the magnet, for it grips them with some power. This "refining" process has actually been carried on commercially with large electromagnets on the banks of the Columbia River where there is a deposit of sand with iron in it. Railroads pick up waste iron, bolts, nuts, etc., along their tracks by drawing a strong magnet along on a truck. These jump from the ground to the magnet and remain there until they are released by turning off the current, "demagnetizing" the magnet.

If you can secure a mariner's compass, test it with your bar magnet and find out which is its north pole. The needle of the compass does not point exactly north, for it points to the *magnetic* north pole of the earth, and not to the north pole of the earth's axis. There are more than a thousand miles between these poles.

Cover both ends of your hanging magnet with paper held on by rubber bands, so that you cannot tell which pole is north or which south. Now test the hanging magnet with your other bar, remembering the law you discovered. Then mark the papers *N* and *S*, and draw them off to see if you were right.

How to Make a Magnet

Now that you have a bar magnet of your own, you can easily make some good magnets with it. The steel that it is the most fun to magnetize is the blade of your knife. Rub one end of your bar magnet, say the north pole (and always the *same* end), along the blade of your knife, always in the same direction. Press gently and move slowly. When you come back for another stroke lift the bar a good way up in the air and come back above the blade. Then go down to the blade and repeat the strokes about two dozen times. If your bar could make marks on the air, it would leave behind it a rough sort of circle. In beginning a new stroke be sure not to hit the knife blade too hard with the magnet, for a jar (and especially dropping) tends to destroy the magnetism in the bars.

Making a magnet of your knife blade will prove whether it is good or poor steel. If poor, it will soon lose its magnetism; but if good, it will retain it for years. Now you can pick up small nails and needles with your blade by just touching its point to them. In the same way you can magnetize any other small piece of steel.

How to Demagnetize

Take an ordinary metal hairpin, bend it out straight, and make it into a magnet by stroking it with one of your bars. Test it with your hanging magnet to see if it is really a magnet. One of its poles must repel the north pole of the hanging magnet, and the other pole attract it. Light a burner on the gas stove and hold the hairpin in the flame with your pliers until it is red-hot all over; then let it cool in the air (about two minutes). Now test it again with the hanging magnet, and you will see that it no longer has any poles, and therefore it is not a magnet. Being iron, it still feels the pull of the hanging magnet, but there is no attraction or repulsion of the poles. Iron is always attracted by a magnet, except when it is red-hot. Then the molecules in the hot iron seem to be so excited by the heat that they do not fall into line at the command of the magnet.

You can have fun trying to make different designs of the lines of force. Place your two books with the paper and filings as before, only instead of putting one magnet in the space, put both there. For each different arrangement of the magnets you will get a different pattern. For instance, *N* to *N*, or *S* to *S*, or *N* to *S*. Then try them endwise, crosswise, etc.

If you want to make these designs permanent you can easily do so. Cut a piece of clean smooth paper for each arrangement that you expect to make. Coat the papers with shellac and let them dry thoroughly. Then make the design by tapping, and carefully carry

the paper to the stove where you can hold it above a burner until the heat has slightly melted the shellac. This will cause the filings to stick, and when the paper has dried again, you will have the design preserved.

Making Magnetic Toys

Magnetic boat. Cut a thin slice off a large cork. Cut two long thin strips of wax paper such as bread comes wrapped in and put them around the edge of the cork, fastening them together at each end with a few drops of hot wax from a burning candle. Now you have the general shape of a boat. Cut the sail of paper. Your mast is to be a long darning needle, but first you must make it into a magnet. Stick it through the paper sail and into the cork, and set your boat in a large pan of water. If it sits lopsided on the water drop a little hot wax from the candle on the *up* side, until it rides even. Use one of your bar magnets to drive the boat. It will back away from one pole of your bar and follow the other. You can lead it round and round the pan or send it scurrying back across the middle. (See Figure 10.)

Magnetic fish. Magnetize a number of small needles. Stick each needle through a small piece of cork, and set them afloat in a big pan. These are the fish. Your fish pole can be a pencil or any small stick. Tie a string to one end of it and on the string tie a horseshoe magnet. Two players are to fish at the same time, and the one who gets the most fish wins. As the magnets will twist around a great deal, they will expose

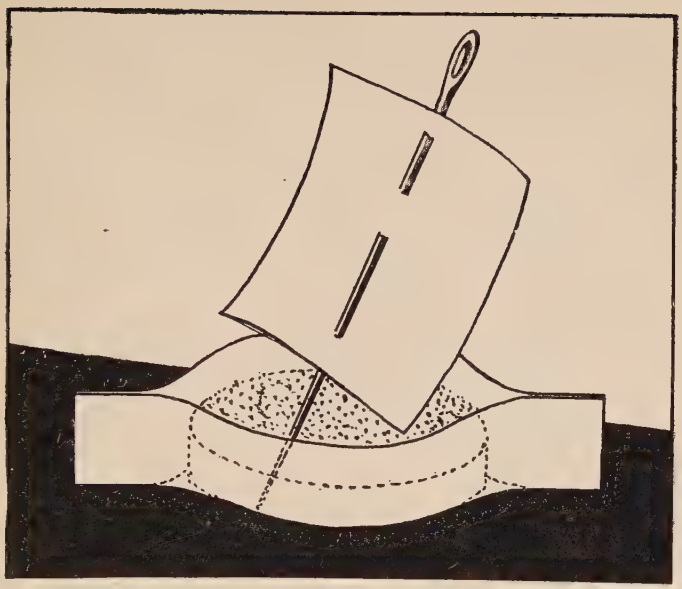


FIGURE 10. A magnetic boat. This is driven by a bar magnet.

first one pole to the needles and then another; so that the needles will be attracted and then driven away. The struggle over the last fish is often very exciting! The fishers must try not to strike their magnets together, for the jar will destroy some of the magnetism in them. One form of horseshoe magnet is shown in Figure 11.

Horseshoe magnets are provided with a little piece of soft iron to lay across the gap between their poles. This is called an armature, and its purpose is to keep all the magnetism in the magnet and prevent its escape. The magnetism in bar magnets can be prevented

from flowing away by laying one bar on top of the other when you are through using them; but you must be sure that *N* is above *S* when you put them away.

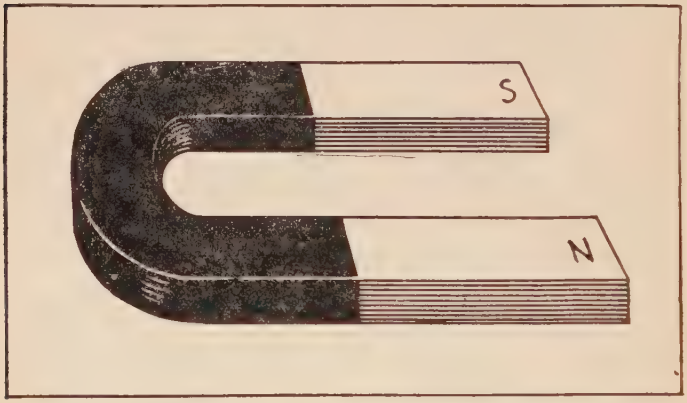


FIGURE 11. Horseshoe magnet.

Laying *N* to *N* for any length of time tends to weaken the force of attraction.

Can you cut off one pole of a magnet. Try it. Magnetize a long hat pin, then cut it in two and test it. You will see that each half, by itself, is a whole magnet. Cut the halves again and test them. Now you have four magnets!

LIST OF WORDS

magnet	lines of force	aluminum
magnetism	attraction	horseshoe magnet
magnetic	repulsion	lodestone
magnetic field	repel	Magnesia
bar magnet	copper	compass
lead	zinc	electromagnet

ELECTRICITY

NO one ever created any electricity. It already exists everywhere about us. While we cannot really make it, we can collect and use it because it stays in and passes through some things better than others. Condensers are those things in which it stays easily; conductors are those through which it will travel; and insulators are those through which it will not travel.

Electricity will go on a visit and do a great deal of work while away; but it insists upon coming back again to the starting place. It is like a gopher because it likes to run into the earth. It always takes a short route when it can. It is like a locomotive because it must have a path made for it to run on. This path is called a circuit. Electricity does not come in the way it went out. If it left by the back door, it comes in by the front.

There are two kinds of electricity, frictional and current. The frictional kind is caused by rubbing. It is not very strong (with the exception of lightning) and is rather quiet in its ways, so we call it *static* electricity. "Static" comes from the Latin and means standing still. Whenever frictional electricity goes from one place to another it makes a spark in passing. Current electricity comes from batteries and dynamos, and is the kind we use for power. The word "elec-

tricity" comes from a Greek word, *electron,* which means amber. Two thousand years ago, the Greeks knew that frictional electricity could be made by rubbing a piece of amber. In those days they did not have ebonite and sealing wax and glass, all of which will give frictional electricity when rubbed with wool or silk.

Electricity and magnetism behave very much alike; but do not confuse them. They are not the same thing. Remember that lightning, though static electricity, is the strongest known electric force. It is so tremendous that it is not possible even to guess its force, much less measure it. When we study the electrophorus, we will make some "tame" lightning, but its manners are very gentle, and we need not be afraid of it.

In your experiments with electricity, you must remember that all materials and apparatus must be perfectly dry. The least bit of dampness will make everything work badly, or perhaps cause it to refuse to work at all.

Into a saucer put some pieces of tissue paper torn up into tiny bits, and some short sections of charcoal from one or two burnt matches. Hold a glass rod or tube over the saucer as you would a magnet. Nothing happens. Rub the glass very hard for several minutes with a piece of silk cloth, and hold it over the saucer again. Now the paper and the charcoal in the saucer fly to the glass and cling to it. Try the same experiment with a rod of ebonite, which is merely hard rub-

ber. The barrel of a fountain pen will do, or the plunger taken out of an old worn-out plant-sprayer makes a fine ebonite rod. The ebonite must be rubbed with a *wool* cloth, not with silk.

To Make an Electroscope

Cut a piece of thick wood (⅞ of an inch thick) about four inches square. Nail a small stick about five inches long vertically to one side of it. To the vertical stick nail a small horizontal stick, or arm, two or three inches long. On the end of this must be fastened a bit of ebonite for insulation—the cap of a fountain pen may be used. The arm can be whittled rounding with a knife, and the cap pressed on over it. This little support will look quite like a magnet stand. Now burn a match until it is thoroughly consumed. Let it get perfectly cool, and then tie around its center a silk thread. Tie the other end of the thread to the ebonite insulator in such a way that the carbon (charcoal) can swing freely, about halfway down to the square base. Trim off the ends of the carbon with scissors until the piece remaining in the knot of the thread is very small—not more than a quarter of an inch long. Do not be discouraged if you cut the carbon in two with the thread once or twice before you succeed in getting it safely tied. This is likely to happen. (In the illustration shown in Figure 12 you can see how the electroscope should look.)

Rub the ebonite rod with the wool cloth and hold it toward the carbon, but be careful not to let them touch.

You will see that the carbon is strongly attracted to the rod. Try the glass rod and the silk, and you will get the same result. Now allow the tip of the rod to touch the carbon, and immediately it flies away. This is the explanation of such strange behavior: At first

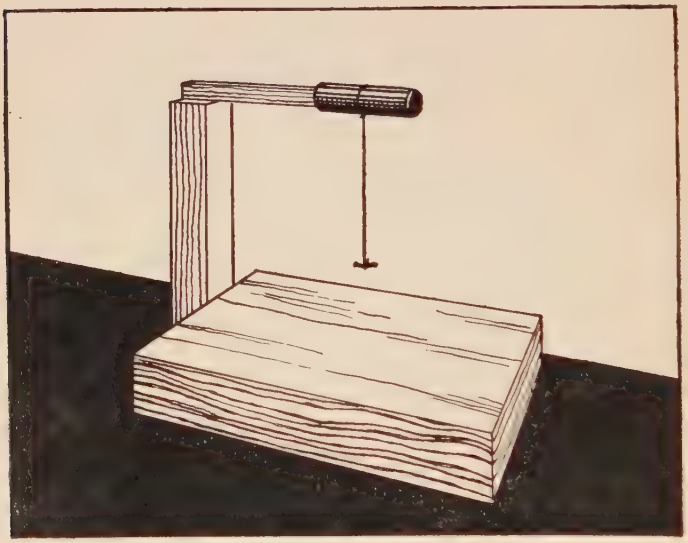


FIGURE 12. A simple electroscope.

the carbon was neutral, and so it was attracted by a charged object, like the rod. When the rod and the carbon touched, a charge of electricity immediately flowed from the rod into the carbon, and they became charged alike. But just as like poles in a magnet repel each other, so do like charges of electricity; therefore, the carbon flew away from the rod.

Bend a wire hairpin as shown in Figure 13. Take off the carbon and lay it away safely in a little box, for future use. In its place tie on the hairpin with a silk thread. Rub a little piece of glass tube (about three inches) with silk and lay it in the wire holder. Make sure that it can swing about freely. Now electrify (rub) the ebonite rod, and hold it near the end of the glass tube. There is strong attraction, showing that the kind of electricity in the glass is different from that in the ebonite.

Scientists call the electricity resulting from the glass and silk "positive"; and that from the ebonite and wool, "negative." The first is marked plus (+), and the second minus (—); but these two terms do not mean more and less, as they do in arithmetic. Glass, ebonite, sealing wax, and India-rubber are insulators; that is, a charge given to them cannot flow away at

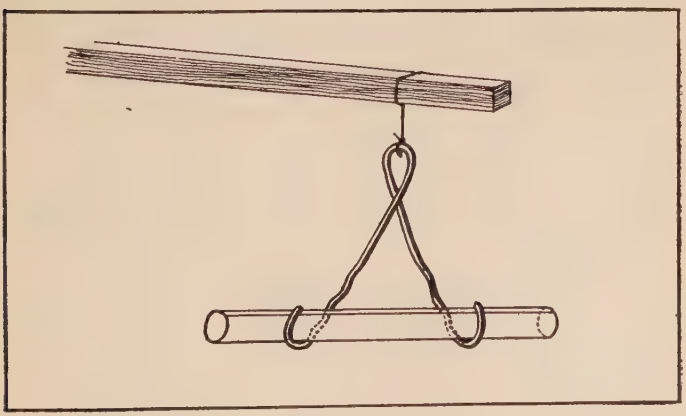


FIGURE 13.

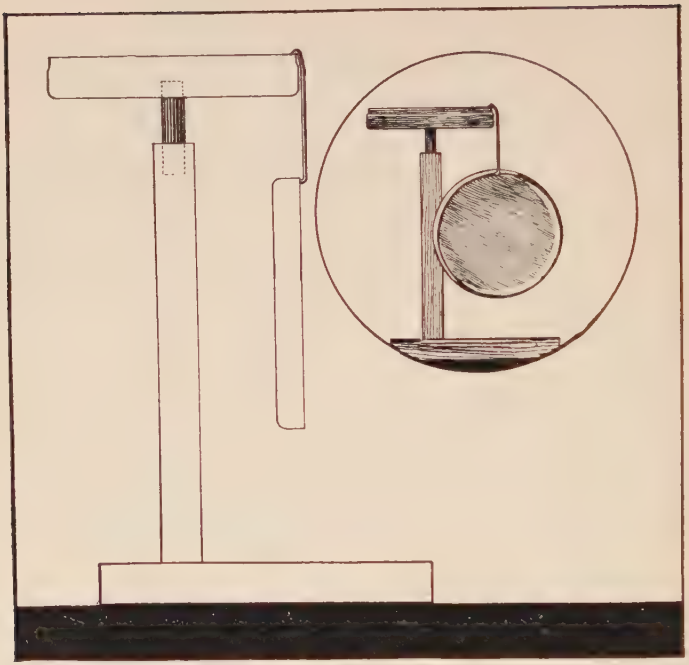


FIGURE 14. Apparatus to perform experiment proving that a neutral body attracts both positive and negative electricity.

once. Metals are conductors. A charge given to them flows away at once through the hand unless the metal is insulated in some way.

Electrify your ebonite rod and lay it in the holder. Point your finger at it. The rod follows your finger as if you were a magnet. Try the same experiment with the glass and silk and you will see the same result. This proves that a neutral body, like your hand,

attracts both kinds of electricity, the positive and the negative. There is another experiment that proves this statement very well. You can build a piece of apparatus to show it. For this you will need a piece of thick wood, about six by eight inches for a base, a ten-inch stick, a fountain pen cap, a round shallow tin box and its cover, and a wire hairpin. Figure 14 shows exactly how to put these together. When the box is hung to its cover by the bent hairpin, it must be able to swing about freely.

Now electrify the ebonite rod and hold it near the upper disk. The electricity will flow into the upper disk, then down the wire, and into the other disk. But the wooden stick is a neutral body; so as soon as the lower disk receives a current it will feel an attraction for the stick and will swing around until it hits it. This experiment works better if an ebonite sheet is used instead of the rod. (You will need an ebonite sheet, anyway, in making an electrophorus.) This apparatus must stand on a bare table when you want to use it. That is, it must be what electricians call "grounded"—connected with the ground so as to make the earth a part of an electrical circuit.

We have now proved the three laws in connection with electricity, and we can state each one in a sentence.

1. Charges of the same kind repel each other.
2. Charges of different kinds attract each other.
3. Either kind attracts, and is attracted by, a neutral body.

How to Make an Electrophorus

For this apparatus you will need a piece of thick wood and the ebonite sheet referred to above. You can use the same tin box you had for the last experiment, or another like that shown in Figure 15, and you will need a little piece of ebonite like the insulating part of your carbon electroscope. Cut the wooden base

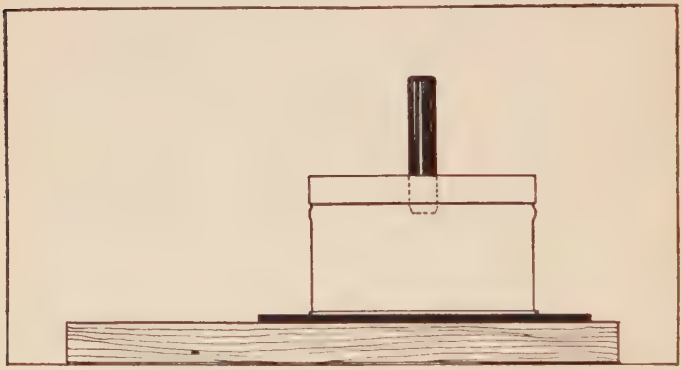


FIGURE 15. An easily made electrophorus.

about ten by six inches. Tack the ebonite sheet to one end of it. The other end is for you to lift it by. Now make a hole through the cover of the tin box into which the fountain pen cap will fit snugly. Put the cover on the box, being sure that it is on tight. Thrust the cap through the hole, and set the box on the ebonite sheet. This is your electrophorus. (See Figure 15.)

To work it you must first lift off the box and rub the ebonite sheet very hard for several minutes with a woolen cloth. Then set the box on the sheet. Now

touch the box with the tip of your finger. Pretend that it is hot and that you are afraid of burning yourself. That will give you the right kind of touch. Then lift off the box by the insulating rod (the pen cap) and, holding it in your right hand, extend close to it the knuckle of your left forefinger. A sharp little spark will jump from the box to your finger. Set it back again on the sheet, touch it as before, and pass another spark. See how many times you can make the electrophorus spark, without rubbing the sheet again. This spark is real lightning.

Set up your carbon electroscope, electrify the electrophorus, and hold the charged box on one side of the carbon in the electroscope, and your hand on the other. The carbon will dash back and forth excitedly. Can you explain this action from what you have learned?

Replace with a baking powder can the shallow tin box shown on the apparatus in Figure 14. The apparatus will then appear as shown in Figure 16. Hang over the edge of the can a length of moistened cotton thread, so that it will be in a loop inside, hanging halfway down, and in two separate ends, hanging halfway down. Pass a spark from the electrophorus to the can and watch the action of the thread ends. They will stand out horizontally. Bring the charged electrophorus near the can and remove it several times, and watch the thread. You can discharge the current from the can, if you wish, by merely touching it with your finger.

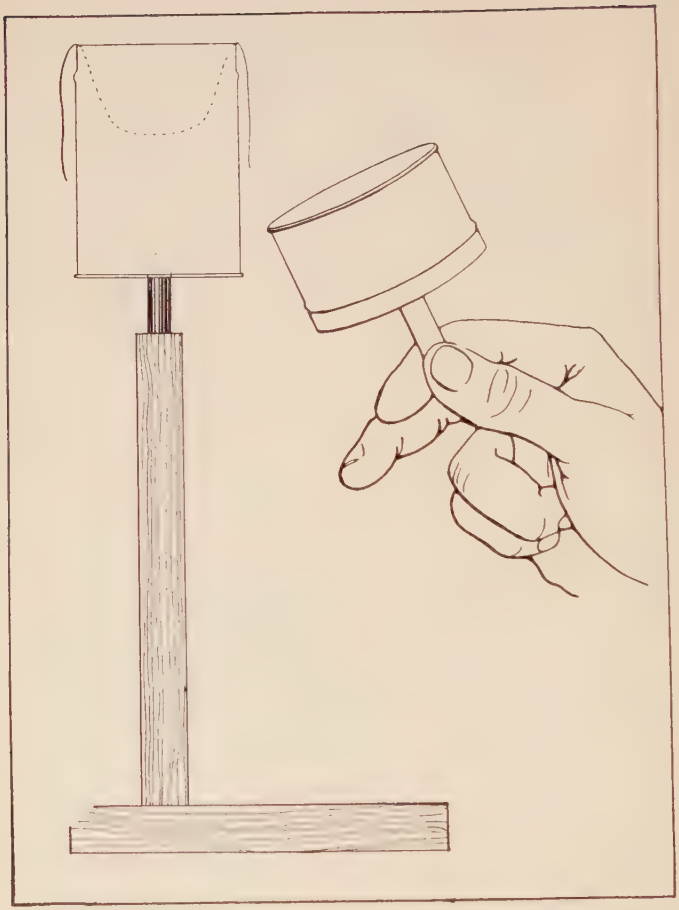


FIGURE 16. This shows electrical experiment with insulated can.

Fill a saucer with pieces of carbon and tissue paper, slightly moistened. Cover it with a sheet of glass. Now electrify the electrophorus and hold it over the glass, but not touching it. The pieces will hop madly up and down.

Lay several pieces of damp tissue paper about the size of your finger nail on top of the electrophorus as it stands charged on its base. Lift it up and watch the papers fly. What does their violent action show you with regard to the movement of the current of electricity in the tin box?

To Make a Condenser

Between two shallow tins place a sheet of glass. The box part of your tin box may be used for one tin, and the cover for the other. Look at Figure 17 and you will see that the bottoms of both tins are touching the glass. Pass ten sparks to the upper tin with the electrophorus. Now lift the condenser by one corner of the glass. The under tin clings and will not fall off.

FIGURE 17. Electric condenser. The bottoms of both tins touch the glass.

Why does it not fall? Because one tin is charged with positive and the other with negative electricity, so there is attraction between them. If we could arrange the tins so that they would come in contact, the two kinds of electricity would rush together and mix, and both tins would be charged alike. Then the bottom tin would no longer be attracted, and would fall. Connect the two tins with a hairpin. The lower one falls at once. The hairpin makes a bridge across which the current runs from one tin to the other.

The Leaf Electroscope

If you can secure a piece of aluminum foil, you can make a leaf electroscope. (Figure 18.) Through the

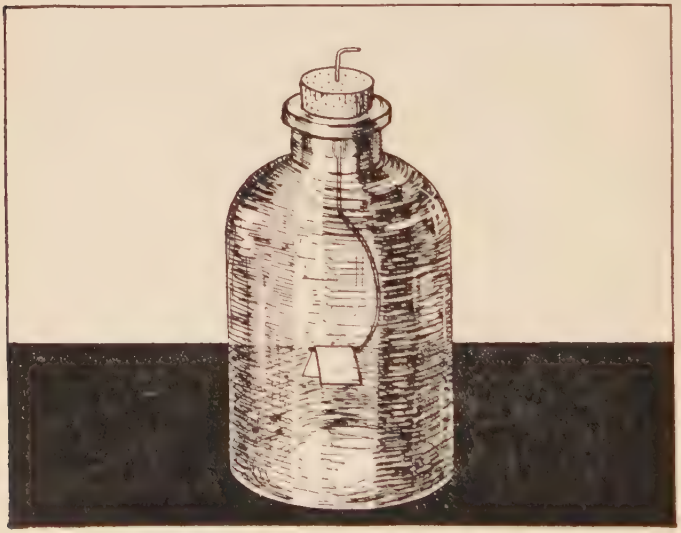


FIGURE 18. Leaf electroscope.

cork of a medium-sized wide-mouthed bottle, thrust a soft copper wire so that the wire will hang down inside. Bend the lower end of it at right angles. On this lower end hang the aluminum foil. This foil should be cut about the shape and size of a postage stamp. It is hard to handle, but with time and patience you can do anything. Bend over enough wire on top of the cork so that it cannot pull through. The foil must be folded in the middle and hung so that the two sides will stand out slightly apart. Charge the ebonite rod and bring it near to the bottle. You will see the leaves of the foil separate. Do the same with the electrophorus, and you will get the same result. This apparatus is for measuring a small charge of electricity. If a heavy charge should come near the bottle, the leaves of foil would be torn to pieces. When the charge is weak, the leaves will not move very far apart. The stronger the charge the farther they will be separated.

Thunder and Lightning

The air is always electrified, but only when enormous quantities of electricity collect in one place do we have an electric storm. Lightning jumping from cloud to cloud or from cloud to earth affects the air in such a way as to cause thunder. The spark and the sound occur at the same instant; but since sound travels much more slowly than light, we do not hear the sound for some time after we see the flash, unless the storm cloud is very near.

Electrical Displays

Sometimes a soft and brilliant fire appears mysteriously on the spars of a ship, especially at the tips of the masts and the bowsprit. Sailors call it St. Elmo's fire, and are often afraid of it; but it is only a silent "brush" discharge of electricity at the ends of the masts or spars. Another more familiar display is the Aurora Borealis, or Northern Lights. It shows often in northern countries, especially in winter. It can be seen sometimes in northern United States, even in summer. To us in this country, it mostly appears as a brilliant white light spreading out fanwise from the north; but occasionally it is colored, chiefly green and purple. We know that the Aurora is an electrical phenomenon because, when it appears, electrical instruments, such as the telephone and telegraph, are disturbed, and sometimes are thrown out of order.

Lightning Rods

When an object on the ground becomes heavily charged with electricity it attracts the lightning. The object of rods is to lead the electricity from the house, never allowing enough to accummulate to attract the lightning. For this reason the rods are not insulated from the house as they formerly were. It is thought the sharp points better attract or discharge electricity. The rods carry the lightning to the ground. Trees having many points of leaves and limbs and deeply rooted act much in the same way, especially trees with

sharp-pointed leaves. They make a sort of natural lightning rod.

Here are three simple experiments that you can try without any special apparatus:—

1. Take a cat into a dark room or closet and stroke her back briskly. What do you see? What causes this?

2. Walk across the floor, scuffing the feet hard on the carpet, and touch someone's knuckle, or a bit of metal. A spark will jump.

3. Cut two pieces of newspaper about four inches square. Lay one aside, and heat the other quite hot. Rub each piece, the hot and the cold, fifteen times with your hand, and place them against the wall. They will cling there. Which do you think will cling longer? Why?

Thus far, we have been considering static electricity. Now we come to study about current electricity. The best way to experiment with current electricity is to buy a couple of dry cells. The dry cell contains "canned" force. How can we show that it will really do work? We will test it with a galvanometer. First we must make one.

To Make a Galvanometer

Buy a small spool of Number 24 insulated copper wire from a hardware store. Wind about twenty rounds of it in a five-inch circle, either about a round object or over your spread fingers. Leave the two ends free and rather long. Mount the coil edgewise

on a wooden base about six inches square. The coil can be held in place by dropping paraffin or drippings from a burning candle on its lower edge. Now the coil will stand up alone, being held by the stiffened

FIGURE 19. A galvanometer

paraffin. (A rather large amount of paraffin is required to hold it.) On either side of the coil fasten two small pieces of wood so that a compass can be set on them, with the coil passing above and below it. The diagram shows how to arrange it. Drive two

small nails in two corners of the base. Scrape off the insulation from the ends of the wire for about an inch, and wind the bare wire around the nails, one end to each nail. Now set the compass in place, and your galvanometer is complete. Figure 19 shows how it looks.

Let us use it now to test the cell. On top of the cell are two poles, one marked plus and one minus. To each pole fasten about six inches of the Number 24 wire, scraping bare both ends for an inch or so. Now touch these ends to the nails, one to each nail, and the needle in the compass will show by its excited behavior that the current from the battery is reaching it. Reverse the wires, putting the left on the right, and the right on the left, and the needle will show that the current is flowing in the opposite direction.

In case you have no compass to use in this experiment, you can easily make one for the galvanometer. Magnetize a needle, and mark its north pole with a drop of red sealing wax. Then tie it by a silk thread to the top of the coil so that it will hang down inside the coil about halfway to the base.

We see, then, by the galvanometer that there is a current, and that it flows in a certain direction. In whatever position the galvanometer is placed with regard to the poles, the needle will always stand out at right angles to the coil. Another way to show whether the current in the cell will do work or not is to make an electromagnet, by means of which you can test its working power.

To make an Electromagnet

At a hardware store, buy a bolt two and a half inches long and five-eighths of an inch in diameter. Screw the nut back until its outside surface is flush with the end of the bolt. Between the inside surface

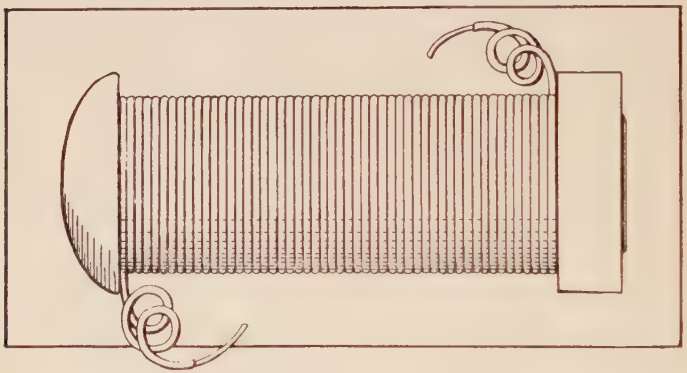


FIGURE 20. Electromagnet to test cell current.

of the nut and the head of the bolt wrap the shank with one layer of paper exactly the right length for this space. This is for insulation. Beginning at the nut end of the bolt, and leaving out a long end, wind the bolt with four layers of the Number 24 insulated wire. When you have finished, leave another long end hanging out, and scrape both ends bare for about an inch. This simple piece of apparatus is an excellent electromagnet. Figure 20 will give you an idea of its appearance.

Hold the two ends of the electromagnet wires against the poles of the cell, and lower the magnet in-

to a cup of iron filings. Immediately the magnet becomes "furred" with the filings. Now suddenly take away one of the wires, thus breaking the circuit, and the filings will fall off. This shows the working of the current in a very striking way. Sometimes freight cars filled with iron are loaded and unloaded with large electromagnets.

The iron filings are troublesome to manage and their weight is so extremely light, that the magnetism remaining in them causes them to cling together. To avoid this trouble, try the same experiment with a handful of small nails. This will work better. Make and break the circuit several times, until you are sure that you understand how the current works, for this "make-and-break" principle, as it is called, is very important. Upon it depends the working of the electric bell and the telegraph.

Electric Bell

Now you are ready to learn about the electric bell. If an electrical repair man will give you an old bell, you will be lucky; for you can take it apart and see how it is made. But first you will need a good bell, or buzzer. This you can buy for about half a dollar at any electrical supply house or hardware store. If you cannot afford to get both a bell and a buzzer, get the buzzer; for you will need one in your telegraph experiments.

A bell and a buzzer are the same, except that the buzzer has no gong. Somewhere on the bell, usually on

the lower edge, you will see two little burred nuts. These, with the shanks over which they fit, are called binding posts, and are for connecting the two wires from the battery. Unscrew one of them a little way, wind the bare end of one cell wire several times around the shank, and then turn the nut down tight. Take the other cell wire in your hand and touch the bare end to

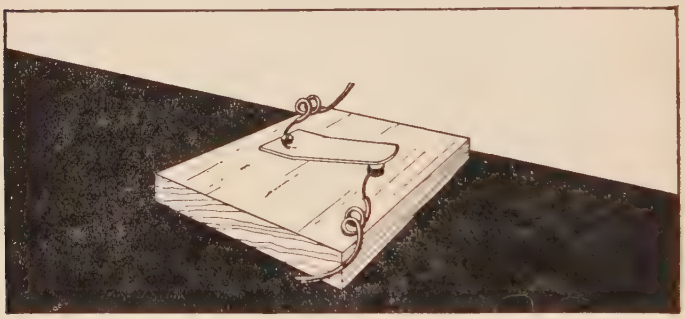


FIGURE 21. A simple push button.

the other binding post. When they meet, the bell rings. You can see how inconvenient a way this is to ring a bell. If we could fasten the wire to the cell and get rid of having to hold it in place, and then break the circuit somewhere else, it would be more convenient.

We can do this by adding a push button to the circuit. A push button is a device in which two connections, such as a binding post and a wire-end, lie one above the other, close, but not touching. When you press the upper connection down so that it touches the lower one, you make the circuit complete, and the cur-

rent can flow and ring the bell. When you stop pressing, the upper connection, being a spring, separates from the lower, and the circuit is broken. The electric current cannot jump across the space between the connections, tiny though it is. You can show exactly how this works by making a push button similar to that shown in Figure 21.

To Make a Push Button

Nail one end of a half-inch strip of any soft metal about two inches long to a piece of wood three inches square. Before you quite finish pounding down the head of the nail, wind around it the bare end of an eight-inch piece of Number 24 wire. Now pound the nail head down tight. Scrape the other end of the wire bare, and fasten it to one binding post of the bell. Bend the metal strip up in a slight curve, as in the diagram, and test it to see if it springs back properly when you let go.

Mark the spot where the free end touches the wood when you press it down, and in the center of this space drive a nail, allowing the head of the nail to stick up about an eighth of an inch. (You can push the strip aside while you are hammering the nail, and afterward pull it back into place.) Around this nail wind the bare end of the loose wire from the battery. Now test your push button and see if it works. If not, some connection is loose, some bit of insulation is in the way, or some bit of rust is on the nail head or on the strip.

The working parts of a bell are usually covered with a little metal box which is held in place by two small clips. You can easily remove it by squeezing the sides together slightly, and at the same time pulling up. Now you can see the two little coils which make the magnet, and the vibrator, or arm, to which the clapper is fastened. When you press the push button you let the electric current flow through the coils, which become magnetized and attract the arm, causing it to swing over to them and, in moving forward, to hit the gong. But this forward movement breaks the circuit by making a little space, as in the push button, across which the current cannot jump. As soon as the current is cut off, the coils are no longer magnets, and cease to attract the arm. The arm is bent so that it has a slight spring, like the strip of metal used in making the push button. It therefore flies back to its first position by the power of the spring. However, when it gets back, it closes the space, and lets the current flow into the coils again. Once more they become magnets, and the arm is jerked over to them, hitting the gong again. Thus the "make-and-break" goes on rapidly, causing the bell to ring as long as you hold your finger on the push button.

Suppose you were to tie down the arm so that when the magnets pulled it over it did not open any space. Then you would have a one-stroke bell; for the arm would lie against the magnets and the gong until you took your finger off the push button. This is how the telegraph works, only instead of the instrument's be-

ing provided with a gong, it has two metal points which strike together and make a sharp click.

The Telegraph and Wireless

For about a dollar you can buy a telegraph practice instrument. Mail-order houses and some department stores carry them. When the key of the telegraph instrument is depressed the two metal points strike together and make a sharp click. When the key is released, another click sounds, but it is not so loud or so sharp as the first click. The difference in the length of time that the key remains down between these two clicks is what makes the difference between dots and dashes. For a dot, the key is depressed the least fraction of a second, and the two clicks will sound close together. For a dash, the key is held down longer, and the clicks will sound a little way apart. There are two codes, the Morse and the Continental.

Morse		*Continental*	
A · —	N — ·	A · —	N — ·
B — · · ·	O — —	B — · · ·	O — — —
C — · — ·	P · — — — ·	C — · — ·	P · — — ·
D — · ·	Q — — · —	D — · ·	Q — — · —
E ·	R · — ·	E ·	R · — ·
F · — · ·	S · · ·	F · · — ·	S · · ·
G — — ·	T —	G — — ·	T —
H · · · ·	U · · —	H · · · ·	U · · —
I · ·	V · · · —	I · ·	V · · · —
J — · — —	W · — —	J · — — —	W · — —
K — · —	X — · · —	K — · —	X — · · —
L — · ·	Y — · — —	L · — · ·	Y — · — —
M — —	Z — — · ·	M — —	Z — — · ·

In the Continental Code, the alphabet consists of dots and dashes. In the Morse Code, it is made up of dots, dashes, and spaces. A space is a pause between clicks. The Morse Code is the harder to learn because it is easy to confuse the space occurring in a letter with the space between words.

In learning the alphabet, begin with those letters which are represented by dots alone; namely, *e*, *i*, *s*, *h*, etc. Next take up those indicated by dashes alone—*t*, *m*, etc. Then learn the combinations. You can carry a copy of the code in your pocket and study the letters without any instrument. Why is *e* the easiest letter? In answering this question, count the *e's* on any page of a book. Then count the *a's*, *o's*, *i's*, and *d's*.

If you can get some one to go in partnership with you and practise with you, you can have great fun. If he lives near you, you can string wires to his house. At any rate you can string them from one part of your house to another. You should have a complete circuit with two dry cells for each instrument, and you should use Number 16 insulated bell wire. A good way to do at first is to write down only what you hear the instrument say; that is, the dots and dashes. Then, after the message is taken, translate it with the code in your hand. You will soon learn the letters by their sound alone.

Here are some suggestions for messages to start with:—

1. Your name.
2. I am learning telegraphy.

3. Samuel Morse was the inventor of the telegraph.
4. The Morse Code is used in sending messages by telegraph.
5. *Warrick Steamship Co., Liverpool, England* Watch landing of passengers from "Dakonia." Suspected Frank Diehl, embezzler, is on board. Height, five feet five and three quarters; weight, one hundred and sixteen pounds. Scar back of left ear. Black hair. Walks with slight stoop. If located, arrest, and hold pending instructions.

NICHOLAS CARTER, *Secret Agent*

The Telephone

Every child has used an oil can. Did you ever stop to think how it works? The thin circle of metal which forms its base is a little too big for the rim which holds it in place. Therefore, when the center is pressed, where the metal bows out, it will cave in, thus forcing the oil through the nozzle.

In the transmitter of the telephone (the bell-shaped piece into which we speak) is a diaphragm, as it is called, which works in the same way as does the bottom of an oil can. Every vibration of the voice acts on this diaphragm like the pressure of the thumb against the bottom of the oil can, making it move in and out. All these movements are carried by the electric current over the wire to a diaphragm in the re-

ceiver, which reproduces the sounds of our voice to the person with whom we are talking.

Dynamos and Motors

A dynamo, in its simplest form, is a coil of wire revolving between the poles of a U-shaped magnet. If you look at Figure 22 you will see how a model of one can be easily made. A real dynamo is a little complicated, but the principle is the same. There are wonderful great dynamos at Niagara Falls, New York,

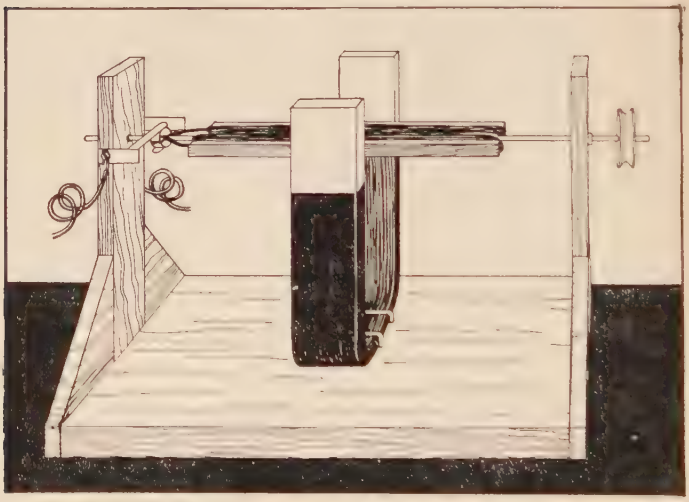


FIGURE 22. Model of a dynamo. You will find the working principle of a dynamo explained in an encyclopedia. When you are sure you understand it you will find it an easy matter to make a model like that shown here. (The armature of this model consists of a flat piece of wood fastened to the shaft and wound lengthwise with insulated wire.)

and at Keokuk, Iowa, on the Mississippi River. You can read accounts of them in books to be found at a public library. The story of how the builders of the dam at Keokuk fought against the water and the huge pressure of the ice in winter, and how the Father of Waters nearly beat them, is a thrilling one.

Many people do not understand the difference between a dynamo and a motor. A dynamo is run by steam or water power, and *makes* the current of electricity for doing work. The motor is run by a current from a dynamo, and *does* the work.

List of Words

electricity	positive	dynamo
sealing wax	electroscope	electroscope
insulator	grounded	telegraph
battery	static	Keokuk
carbon	neutral	frictional
amber	motor	lightning
telephone	galvanometer	St. Elmo's fire
ebonite	Niagara	Aurora Borealis
insulate	negative	discharging
knuckle	current	circuit
reverse	conductor	Continental Code

LIGHT

WE see objects because rays of light come from them to our eyes. The rays may come from the light itself or be reflected by the objects. You see this page because it reflects the rays of light falling upon it. Light travels in waves in space, somewhat like waves in water, but the vibration is so rapid that you can no more see it than you can see an airplane propeller in motion.

Light always moves in a straight line. You can change the direction of the line, but you cannot make light follow a curve. The things that will turn light out of its original straight-line course are prisms, lenses, bodies of water, glass, magnets, etc. Magnets will turn light only under very special conditions; so you cannot prove this unless you have a laboratory fitted up with scientific apparatus. A beam of sunlight striking a paper gives the impression of white light.

People thought for a long time that such light was "pure," that is, not a mixture. Newton showed them how to take light apart with a prism, as you can easily do. When you try this experiment, choose a bright, sunny day, and a room in which the sunlight strikes a window. Shut out all the light except that entering through a tiny opening, and in the opening

hold a prism. Let the light going through the prism fall on a clean piece of white paper, and on that paper you will see spread out the different parts of light; that is, a beautiful rainbow. Prisms cost only a few cents, and can be bought in the toy section of department stores, or from any kindergarten supply house. The glass prisms on an old-fashioned lamp or candle shade are excellent for this experiment. This process of separating a ray of white light into its colored parts is called dispersion. Look at the colors on your paper and you will see that they lie in a certain order. Violet is at one side, and then come indigo, blue, green, yellow, orange, and at the other side, red.

The rainbow colors always lie in this order. If you take the first letter of each color and put these letters together in this order to make a word, you will get "vibgyor." Accent it on the middle syllable, and give the *g* its hard sound. Of course there is no such word, but we may make it up to help remember the order of the colors.

Perhaps you find it hard to believe that *white* light is made up of these colors. If you could take all the colors and put them together and get white, then you would be sure of it. You can do this by making a color disc.

To Make a Color Disc

Cut an eight-inch disc from a strong cardboard box. With a pencil put a dot on the rim at any point. Beginning at the dot, measure with a ruler six and three-

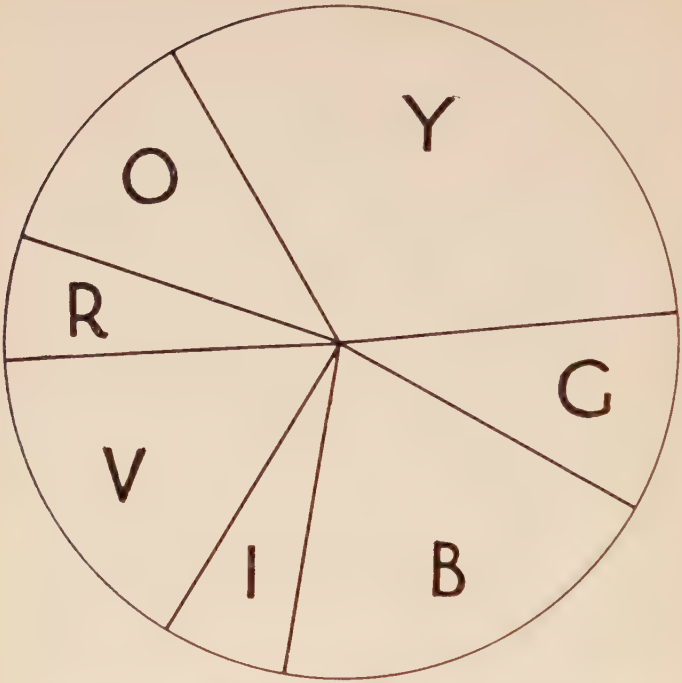
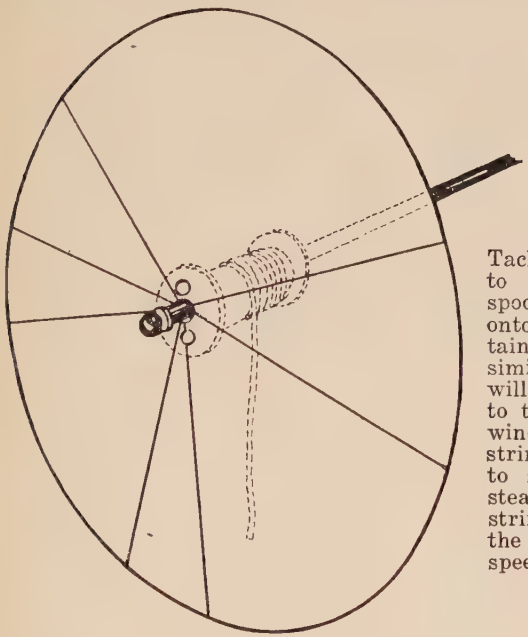


FIGURE 23. Diagram showing divisions of color disc.

quarters inches straight across the disc to another point on the rim and place another dot there. If you have trouble in doing this, stick a pin into the edge of the ruler at six and three-quarters, and keeping the end of the ruler on the first dot, swing it around until the pin rests exactly above the rim. Looking at Figure 23 will also help to show you how to do this. As the ruler lies on the circle, its edge will form the chord of a sector of the circle. Now draw straight

lines from the two dots to the center of the circle, and mark the space between them "yellow." Move the end of the ruler over to the second dot, and measure off two and three-eighths inches. Mark the space "green." Keeping on as before, mark off four and five-eighths



Tack the color disc to the end of a spool, slide the spool onto a brass curtain rod or any similar rod that will allow the spool to turn freely, then wind the spool with string as you would to spin a top. A steady pull on the string will whirl the disc at an even speed.

inches for blue, one and one half for indigo, three and three-fourths for violet, one and one-half for red, and mark the remaining space orange.

Each space is to be filled with the color marked on it. The best way is to cut "pieces-of-pie" of colored paper to fit the spaces and paste them on the disc. You can

buy colored paper at the same places where you can buy prisms, and from paper stores. When the paste is dry, tack the disc with a rather large tack to the end of a spool. Slide it onto the rod as shown in the diagram, so that it will whirl around easily. A string can be wound around the spool and pulled quickly, just as you jerk a top string. This causes the disc to whirl rapidly and mixes the colors together.

When you have tried it you will see that the disc is white, as long as it turns around rapidly. The only possible mistake in making the color disc is in not getting just the right colors. They should be pure colors, or what the scientist calls "spectrum" colors. If the red paper that you use is scarlet or crimson, and not real red, or if the green or the blue should be a little muddy in shade, the disc when whirled will not be pure white, but will be grayish or brownish.

The Bending of Light

The subject of the bending of light through different kinds of prisms is too difficult for you to understand; but anyone can show how a body of water bends light. Fill a glass with water and put a pencil in it. Hold it on a level with your eyes, and look at the pencil. It does not seem to be straight, but has an angle at the point where the pencil enters the water. The explanation is that the rays of light which bring to our eyes the image of that part of the pencil beneath the water, are bent by the water in a direction different from the rays which bring us the image of the part in the air.

In the same way, things seen through the glass of a window are not exactly in the place where they seem to be.

A single line of light is called a ray. A group of rays is called a beam. The light of a searchlight and that of a lighthouse is a beam. When we can catch a

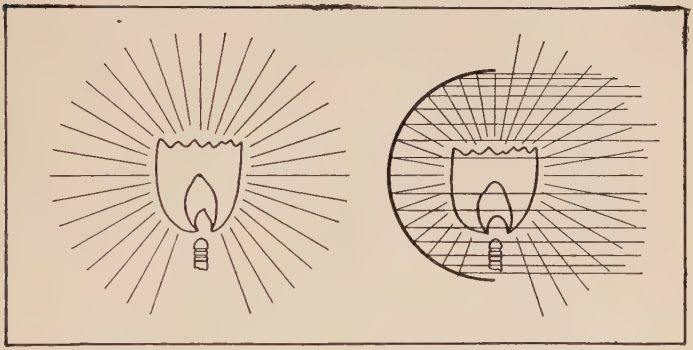


FIGURE 24. The left-hand drawing shows a gas flame when there is no reflector to direct the rays. The right-hand drawing shows how a reflector bends the rays in the same direction, into a beam of light.

number of scattering rays and bend them into a beam so that they will all go in the same direction, we can make a very strong, bright light. This is what is done by reflectors and prisms used in the lantern of a lighthouse.

Look at the illustration of the gas flame in Figure 24, and see how the rays go out in all directions from the free flame; but from the flame with a reflector the up-and-down and left-hand rays are caught and sent back to move forward in the same direction as the

right-hand rays. If you have ever seen a spherical pin ball stuck full of pins, you will have a very good idea of the shape of the lighted space around a flame. The pins are like the rays. Reflection is the turning back of rays from some bright surface.

Ordinary mirrors cannot be used where there is much heat with the light, for the heat would vaporize the mercury on the back. Mirrors of polished metals like silver, tin, and nickel are used instead.

The surface of a lake or pond often gives a very bright reflection. Here is an experiment which shows how we can make a glass of water act like a mirror. Fill the glass two-thirds full of water, and hold it up above your eyes, so that you can look up through the side of the glass at the top of the water. Now hold a pencil above the top of the water. Can you see it? Not any more than if you held it behind a mirror. Lower the pencil slowly. You cannot see it until it is underneath the surface of the water.

Empty the glass. Write your name in large black letters on a little slip of paper and put it into the bottom of the glass, name up, with a small stone on it to prevent it from floating. Now fill the glass again, and hold it above your eyes. You can see your name and the paper and stone reflected from the under side of the top of the water. Tip the glass slightly, and turn it slowly around until you can see the name. Hold very carefully, so that the level of the water will be disturbed as little as possible while you turn the glass around.

Colors

When we say that we have painted the fence green we have not stated the matter correctly. What we have really done is to spread over the fence a substance which absorbs all the colors except green. The green it will not absorb, but throws it back to our eyes, so that the fence looks green to us.

Colors go in pairs, and have their favorite chums. The chum of yellow is blue; and green has red for its running-mate Yellow and blue light—*light*, please note, not pigment,—if added together as we added the rainbow colors, will give white light. Red and green added together also give white light. These facts can be proved with color discs in the same way that we proved how the seven colors make white. Any two colored lights which, added together, make white light, are said to be complementary to each other. Each completes the other in making white. You can prove this statement by a simple experiment.

In the middle of a sheet of white paper paste a circle of bright red paper two inches in diameter. Place behind the page of white paper a blank sheet of the same size, and hold them both at arm's length. Stare hard at the red spot for a minute or two, and then suddenly whisk it to one side, leaving the blank sheet exposed. On the blank sheet you will see a green spot the same size as the red. The reason for this is that as you stared at the red spot, your eyes grew more and more tired of red, until they had developed what scien-

tists call a "fatigue for red." When you took away the sheet with the red on it, and your eyes rested on the blank sheet, they were unable to see the red any longer because of that fatigue. All that they could see was the color which, added to red, makes white. As your experiment proves, this color is green. You can prove the same thing for blue by pasting a yellow spot on a page. A few people are color-blind; that is, they cannot tell one color from another. Because of this there are some kinds of work they cannot do. For instance, they cannot be trainmen or sailors, because they cannot distinguish between the different colored lights.

The Spectroscope

This wonderful piece of apparatus is arranged so that the light from any object can be made to pass through a glass prism and fall upon a screen.

If the light comes from an electric discharge through any gas (the light from green lamps photographers use are discharges through mercury) the light gives a pattern of bright stripes instead of spreading out into the series of colors as sunlight does. No two materials give the same pattern. By allowing light from a star to pass through a spectroscope, astronomers can tell of what substances the star is made.

Chemistry of Light

Light has wonderful chemical effects. It is now used in various forms to cure diseases, but its best known chemical action is that on the photographic

plate or film. Plates and films are covered with a substance which is very sensitive to light. There is a kind of paper coated in like manner, which is called blueprint paper. It is cheap and can be bought wherever artists' materials are sold, and at many school supply stores. It is rather hard to handle, but you will not have any trouble with it if you will keep it carefully wrapped in several layers of dark-colored paper, away from the light.

When you wish to use the paper, unroll it, quickly tear off a small piece, and roll up the rest again. Pin up on the wall the little piece you have torn off and watch the effect of the light on it. When you first tear it off it is a pale greenish-white, but it soon turns bluish. After it has hung about five minutes in the light, wash it in a basin of clean water for another five minutes, and you will see that it has turned a deep, strong blue. It will keep this color permanently.

Now tear off another piece and lay on it some small object such as a key, and put it on the windowsill in a strong light. Let the light act on it for a few minutes, and then wash it as before. On the paper is a perfect image of the key in white, while all the rest of the paper is dark blue. This experiment proves that it is the light which makes the change in the coating of the paper; for under the key, where the light cannot reach it, it is white. You can repeat this experiment with a fern frond, or a spray of leaves, and get some most exquisite effects. The white part stays white, just as the blue stays blue.

Optical Instruments

Mirrors. Stand face to face with another person and let each raise the right hand. The raised hands will be diagonally opposite. Now stand face to face with your image in the mirror, and raise your right hand. The hand which the image in the reflection raises is not diagonally opposite, but directly opposite.

Lenses. The debt of science to the lens is enormous. Without the lens of the microscope we should never have been able to fight certain diseases as we now can, nor should we have known a great many things about the structure of living tissues. With the lens of the telescope we can explore the sky and learn multitudes of unguessed things about the planets, the sun, and the stars. Without lenses for spectacles and eyeglasses, the eyes of a great many people would be almost useless to them.

In all lenses the effect that they have is due to the bending of rays of light. A "burning glass," as children call it, is a lens. You could hold a piece of paper in the sun all day, and nothing would happen to it; but hold a burning glass over it, and in a few moments it catches fire. The lens bends a number of the sun's rays to a single point, and that point has heat enough to cause fire. A match head can also be lighted by a burning glass. It is even possible to make a lens out of a piece of ice which will light paper. This has been proved by arctic explorers. When you wish to set fire to anything with a burning glass, you will find it necessary to move the lens toward, and from, the

object until you have the best focus of the beam of light. A little experimenting will soon show you the exact point of this focus.

Archimedes, a noted Greek inventor, is said to have set fire to the ships of the attacking Romans by using a huge burning glass which he had made of a series of lenses.

Artificial Lighting

Other optical instruments are the stereoscope, binoculars, opera glasses, the camera, the microscope, and the telescope. Whenever you can get a chance to use any of these study them and learn all you can about them.

The history of artificial lighting is an interesting subject to look up. There is plenty of reading about it and many pictures. The first light that man had was a burning stick hastily snatched from the fire. Afterward came the little saucer of fat, or oil, with a piece of a bulrush dipped into it for a wick. Then came the oil torch, the candle, the oil lamp, the gas jet, and finally the electric incandescent bulb.

Substances are named as they treat light:—

A transparent body is one through which we can see because it lets the rays of light pass regularly through it.

A translucent body is one through which we cannot see, but which lets rays of light irregularly through it.

An opaque body is one through which we cannot see because rays of light cannot pass through it.

The Eye

The eye has two lenses which help us to see. They are arranged something like the lenses in a telescope. Light falls on any object that we see and is reflected to our eyes. Here the reflection goes through the cornea, the transparent portion in the front part of the

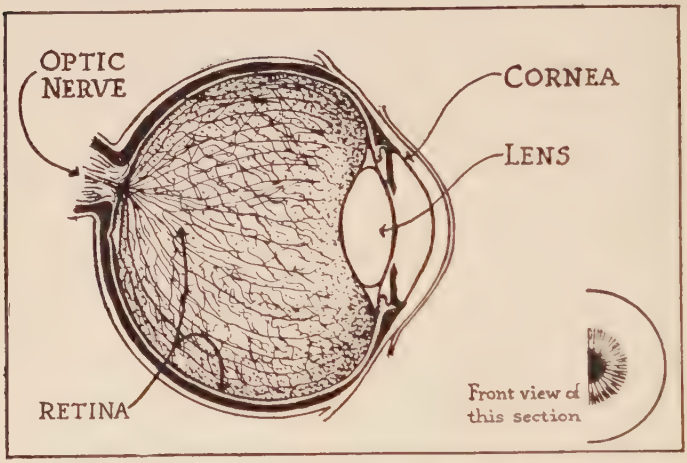


FIGURE 25. This drawing shows the different parts of the eye.

eye, then through the crystalline lens, which is a circular clear structure farther back in the eye, and is finally spread out over the surface of the retina (inner coat of the eyeball containing the nerves of sight). As the sound of the voice is carried over the telephone wire to the person at the other end, so is the reflection of the object carried over the optic nerve (special nerve of sight) to the brain. (See Figure 25.)

You can easily make a little model of the inner surface of the eye with its optic nerve. Take an old tennis ball and cut it in halves. Bore a hole in the middle of one half. Find six or eight inches of thick string—a string that is made up of many strands twisted together. Put the string through the hole, leaving about two inches inside the half ball. Now fray out the two inches until all the little strands are unwound and separated. Coat the inside of the half ball with paste or glue, and spread out the strands over it as evenly as you can. When dry, trim neatly around the edges with scissors. This makes an excellent model of the inside of the eyeball and illustrates how the optic nerve comes in at the back and spreads out in many, many fine fibers. In fact, the eye is a little camera. The image of any object we see is upside down on the retina, just as it is on the ground glass of a camera. In some way not understood by scientists, the image gets turned right side up when it arrives at the brain as a sensation. Since we have two eyes, you may wonder why we do not get two images. We do, but they are blended together by the optic nerve in such a way that they reach the brain as one impression.

Sometime when you have an opportunity to look at an empty camera, work the diaphragm both ways. After you have done this, you will understand better how the pupil of the eye works, for it is a diaphragm. When the light is strong, the pupil closes, so that the nerve will not get too much light. When the light is

dim, the pupil opens, so that we may have more light passing to the nerve, and be able to see better.

Here is an experiment that you can try with the pupils of your eyes which will show this action quite plainly. Light a gas jet and turn it low. Stand under the light with a mirror in your hand held so that you can see the pupils of your eyes. Now turn up the light

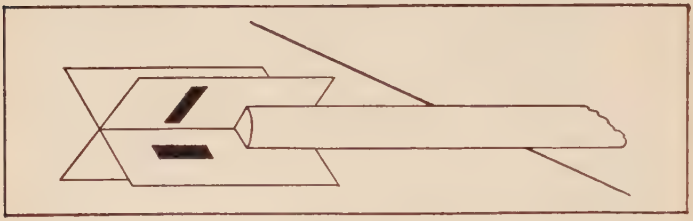


FIGURE 26. Apparatus to use in experiment showing that the retina of the eye holds the reflection of an image for a time.

slowly, and you will see your pupils close as fast as the light brightens. Look at the pupil of the cat's eye in daylight and again at night and see how much larger it is at night.

When an image is reflected into the eye, the retina will hold it for several minutes after the light is cut off. Prove this by staring hard at the window for one minute, and then shutting the eyes. You will still keep on seeing an image of the window, even though your eyes are shut.

You can make a simple piece of apparatus to show this fact. Take about one foot of three-eighths inch dowell rod, and make two saw-cuts an inch deep at

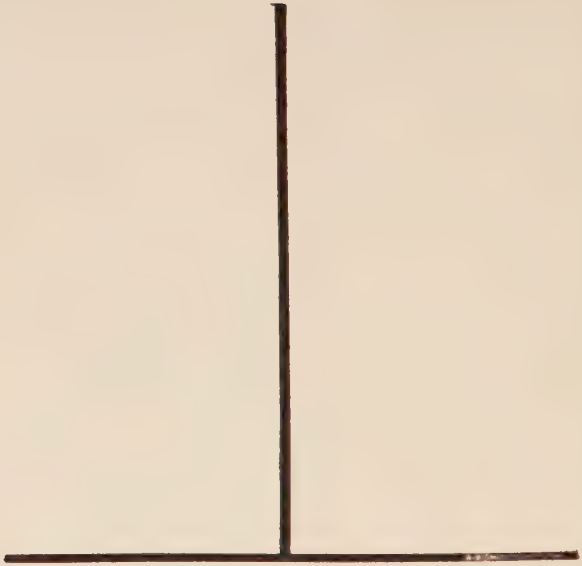
right angles with each other, in one end. These cuts are in the direction of the grain. Now cut two little strips of thin cardboard about one and one-half inches long and seven-eighths of an inch wide, and halve them together so that they cross each other. On one of the four little wings thus formed paint a vertical stripe in bright red. On the next wing paint a horizontal stripe the same color. Leave the other two wings blank. (See Figure 26.)

Now set the crossed strips on the crossed cuts and work them down to the bottom. Tie a string tight near the end to hold the cardboard in place. As you roll this rod along the edge of the table with the flat of your hand, you get a rapid rotation of the four little wings, and your eye receives in rapid succession first an image of the vertical stripe and then the horizontal. But since the impression lasts a while on the retina, you seem to see a red cross on the wings. This experiment will work better if the rod is mounted on two bearings like the rod of the color disc. A string can then be used to whirl the rod, and the red cross will appear steadier and plainer.

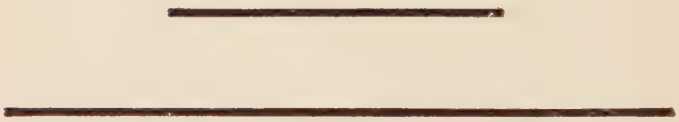
Optical Illusions

Although the eye is so quick and wonderful, it is easily deceived. Try some of the experiments suggested in the accompanying illustrations and see how easily your eye can make a mistake.

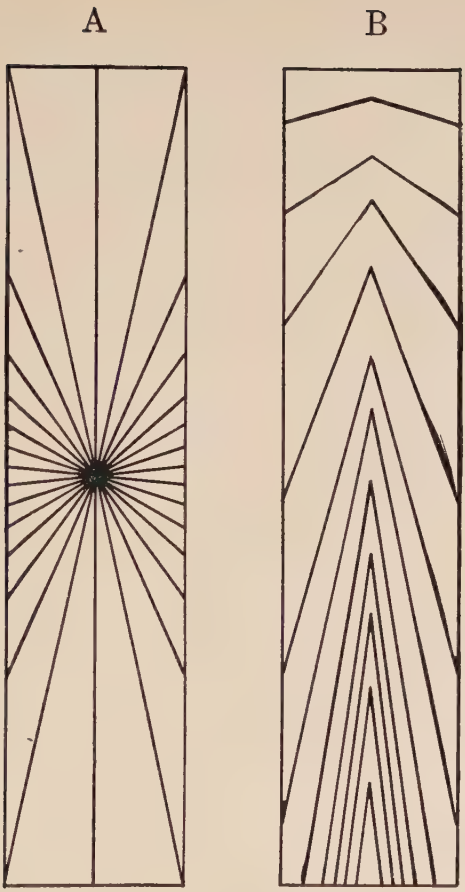
To see through a book.—Make a roll of stiff paper about one and one-half inches in diameter. Cover one



OPTICAL ILLUSIONS. Which is the longer of these two lines?



OPTICAL ILLUSIONS. The longer of the two lines above seems less than twice the shorter.

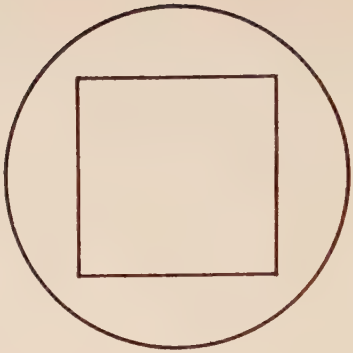


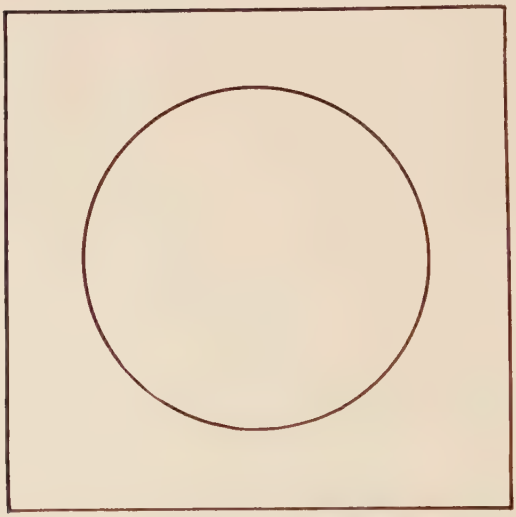
Optical Illusions. A appears broader at the center than at the two ends. B appears narrower at the bottom than at the top.

OPTICAL ILLUSIONS. These parallel lines appear to converge because of the diagonals.

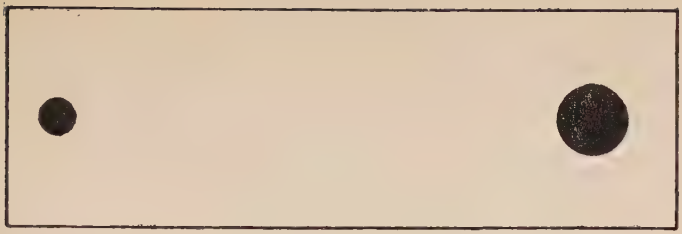
OPTICAL ILLUSIONS. These parallel lines appear to diverge because of the diagonals.

OPTICAL ILLUSIONS. These lines appear to be of different lengths; but are, in reality, all the same length.

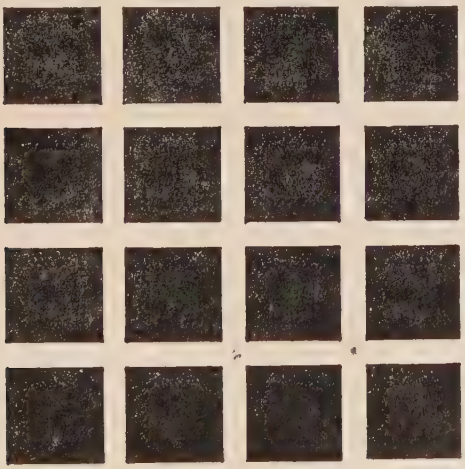




Optical Illusions. The circle inside the big square looks larger than the circle around the little square.



Optical Illusions. At the point where the optic nerve comes into the retina, there is no sense of sight. This place has been called the "blind spot." To locate it: Place the page twelve inches from your face. 2. Hold the left eye closed. 3. Look steadily at the small dot. Although not looking at the large dot, you will see it out of the corner of your eye. 4. Move the page slowly toward your face. When the large dot fades out of sight, you have reached the blind spot.



Optical Illusions. The crossing of any of the white lines which you see, but at which you are not looking directly, appears to be shaded. Look directly at any crossing and it looks white; but those near it seem to be shaded.

eye with the roll, but keep both eyes open. Hold the roll at right angles with your face. Now hold the edge of a closed book against the inner side of the roll—that is, the side next your nose. You will appear to see through the book!

To "make money."—In the middle of the bottom of a small tin pan put a quarter of a dollar. Set the pan on a table. Stand in front of it and walk backwards until the coin cannot be seen. Mark the spot where you stood when the coin went out of sight. Now call some one who is just your height to come and stand on the marked spot. Tell that person to look at the pan and see how you can turn water into money. Then pour water into the pan (slowly, so as not to disturb the coin or make it change its position), and because of the bending of the rays of light by the water, the coin will come gradually into sight.

List of Words

prism	lens	mirror
microscope	Archimedes	translucent
blueprint	camera	opera glass
reflect	optical illusion	reflector
transparent	spectacles	color-blind
complementary	pigment	photograph
crystalline lens	optic nerve	spectrum
beam	rainbow	opaque
telescope	cornea	lighthouse
retina	pupil	diaphragm

SOUND

SOUND depends upon two things: first, vibration, and second, the ear. Vibration is a rapid trembling to and fro. Stretch a rubber band between two points and pluck one side of it. You have made it vibrate; that is, swing back and forth very rapidly. Its movement is like that of the spokes in the whirling wheel—so fast that you cannot actually see it. But you will notice that the rubber band seems to be surrounded by a little gray cloud. Remembering your experiment with the whirling rod which had red stripes on it, can you explain this gray cloud? The rubber band is a vibrating body held at both ends; but a body can vibrate when held at one end, under certain conditions. You can prove this with a vibration stick.

To Make a Vibration Stick

From a piece of wood an eighth of an inch, or less, in thickness, cut a three-quarter-inch strip three feet long. Take a very thick piece of wood (if you have none, nail together several thicknesses of thinner wood) several inches square, and in its center cut a mortise at least an inch deep that will fit the end of the long strip. Fit the end in the hole and glue it in. It should fit tightly.

To work the vibration stick, first fasten it securely to the edge of a table. A handscrew is good for this, as you can dismount the block when you are through using it. Pull the long strip to one side and let go. It will vibrate from side to side. If the strip were thicker, it would not vibrate so well. If it were very thick, it would not vibrate at all.

Vibration and Resonance

The body which produces a sound may be a string, a bell, a tuning fork, a column of air, etc. Whatever it is, the sound goes out from it in every direction, just as the rays of light go out from a flame, and just as the pins stick out in the spherical pin ball. When a church bell rings, you hear it whether you are north, south, east, or west of the bell.

Sometimes, in a church, when the organist puts his foot on the key of a big bass pipe, one can *feel* the vibrations going through the floor. In this case, it is the column of air in the pipe that vibrates. The largest pipes in some church organs are big enough for a child to crawl through; so you can see that the column of air in them must be very large. With an ordinary bottle you can prove how a column of air vibrates. Choose a tall, thin one, with a narrow mouth, and blow into it. Your breath will set the column of air inside it in vibration, and it will give you a tone. The larger the bottle, the deeper the tone.

We learned that light travels very fast. Sound also travels fast, but not nearly so fast as light. Sound

travels eleven hundred feet in one second, or one mile in five seconds.

Most people know that the tubes in a radio set amplify the incoming current, but did you know a sound could also be amplified? When a sound is amplified it is said to be resonated, and that which does the amplifying is a resonator. Some substances will resonate sound better than others. It is fun to explore the house with a tuning fork, and find out by your own discovery what substances will increase the sound.

A tuning fork can be bought from almost any department store in the musical instrument section for from ten to twenty-five cents. Hit the fork a light blow against something solid and set it vibrating. Then try holding the opposite end against different things. Try it on the plaster of the wall, and on the glass of the windowpane. Now try it on a panel of a door, and you will discover that wood is a very good resonator. Turn an empty cigar box upside down on a bare table. Set the fork vibrating and touch the other end to the middle of the box. This will give you the best result. Not only does the wooden box resonate the sound, but so, also, does the air under the box. No better resonator for sound than wood has ever been discovered. That is why so many of the best kinds of musical intruments are made of wood.

The ground resonates sound somewhat. You know that by laying your ear to the ground, you can hear a galloping horse some time before you can hear it if you are standing up.

Here is an interesting experiment to show that wood is a good resonator. Rest each end of a thin board about ten feet long on a chair seat. Stand the board up edgewise so that about one inch of it rests on each chair. Ask some one to stand at each end and steady it for you by holding it with the thumb and first finger. The board must not be grasped in the whole hand. Now hold a watch at one end of the board and press it against the side of the board. Have some one press his ear to the board at the other end and listen. If he cannot hear the watch ticking, move it a few inches toward him and try again. The distance will depend upon the size of the watch and the thickness of the board. The ticking can be heard through the board at a greater distance than it can be heard through the air.

Deaf people can hear in a certain sense—that is, they can feel vibrations. It is said that the wonderful deaf and blind girl, Helen Keller, can enjoy music by laying her hands on the piano case.

Here is an experiment to perform with your tuning fork, that is great fun. Ask a friend if he knows that he can hear with his teeth. When he says, "Of course no one can hear with the teeth!" show him your tuning fork, and let him listen to its sound. Then tell him to stop his ears and open his mouth. Set the fork in vibration and touch one of the prongs to one of his teeth. He will be very much surprised at the way he can feel the vibrations go jingling through his head-bones. Afterward you can explain to him just how

his skull bones carry the vibrations to the inside of his ear.

Sound moves in waves like the ring-waves that we see when we drop a stone into still water. It must be remembered, however, that water waves move only on the surface of the water, while sound waves go out from the sounding body in *every* direction. Scientists are able to measure the length of sound waves very accurately. They tell us that when a man with a heavy voice speaks, he makes sound waves from eight to twelve feet long.

We learned how the rays of light could be bent and focused so as to run in one direction. The same thing can be done with sound. When we can bend a number of sound rays and make them run in the same direction, we can greatly increase the strength of the sound. A megaphone does this. It catches the rays of sound going out to the right and the left of the speaker's mouth, and those going up and down, and bends them to run parallel with those going straight out. In a speaking tube the same thing happens. A whisper can be distinctly heard through a speaking tube a half mile long.

When sound travels through the air, the effect is like that of a train of freight cars bumping together when the engine stops. The little particles of air lying next to the sounding body bound outward, being driven by the blow of the vibration. They hit the particles next to them, and those hit the next beyond, and so on and on, until the sound comes to the ear.

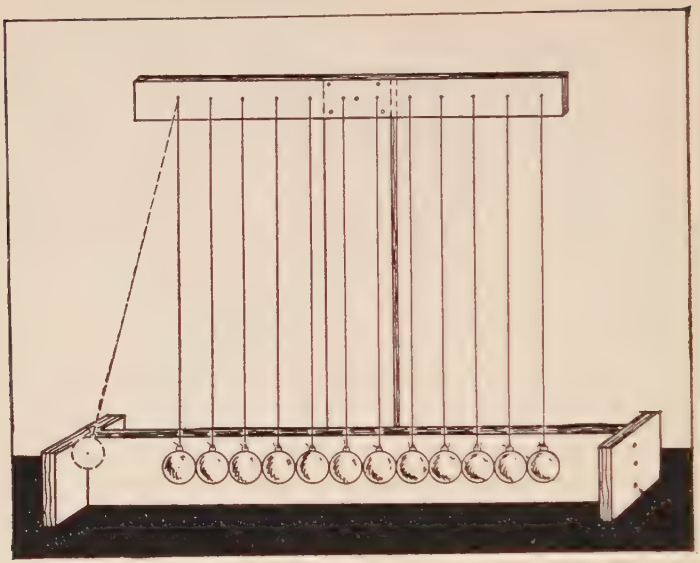


FIGURE 27. An easily made apparatus to show how sound travels.

You can make a piece of apparatus that will illustrate this very nicely. First make a frame as in Figure 27. This should be in the shape of a T about two and a half feet high. Nail the crosspiece to the upright, and make any sort of base that will hold it up firmly. Along the middle of the top of the T drive in a row of little nails. From a kindergarten supply house secure a dozen wooden balls having a hole through the center. Hang the balls on these nails, all on a level with each other. The balls are hung to the nails by means of strings. Run one end of the strings you are to hang the balls by through the holes and tie

knots in the strings so that the balls will not slip off. The distance apart for the nails will depend on the size of the balls. The strings should hang nearly vertical, and the balls must touch cheek to cheek. Behind the balls there must be a strip of smooth wood for them to roll against, and they must hang so that they touch this strip when at rest. The balls will represent the particles of air.

Now draw out one of the outside balls as far as you can and let it go. It will roll along the back-board and hit the second ball, which will hit the third. The third will hit the fourth, the fourth the fifth; and so on all the way along the line. When the impact (that is, the force of the blow) comes to the last ball at the other end, that one will fly out as much as the first ball was drawn back. It takes a long while to describe all this action; so you might expect the impact to take some time in reaching the last ball. But you will see that the very instant the first ball hits its neighbor the last ball flies out. This is the way the particles of air behave when they receive an impact from the vibrations of a sounding body.

How do we know that it is the particles of air that carry sound to the ear? A scientist would answer that question by a very striking experiment. He would place an air pump on the table and in the dome lay an electric bell. He would connect the bell by wires with a circuit, and then set the dome of the air pump in place. The dome is like a great glass jar and fits down tightly over the base. Now the scientist would

turn a switch and set the bell ringing. Although the bell would be under the glass you would hear it quite plainly. Then he would set the pump going, and this would begin to suck out the air from under the dome. The more air the pump sucked, the fainter would the

FIGURE 28 a. Sound waves formed by a tone—a regular, orderly succession.

bell sound, until finally you could not hear it at all, though you could still see the clapper striking the gong.

The difference between a tone and a noise is in the shape of the sound waves caused by them. Look at Figure 28 a in the drawing, and you will see that the sound waves made by a tone have a regular pattern. Look at Figure 28 b, and you notice that the waves made by a noise are all irregular, and differ from one another in shape and size.

The strings of a piano vibrate from thirty-two times per second in the bass, to four thousand times per second in the treble. You can try an experiment on the piano. Open the top, and lay a large book or some

FIGURE 28 b. Sound waves formed by a noise—an irregular, jagged, and formless succession.

solid object between the top and the case so that there will be no danger of the top's falling on your head. Then strike some key near the left-hand end, that is, the bass, and lay your fingers on the string. You should carefully wipe your fingers before touching the string to prevent any moisture from making rust. Now strike a key at the other end, the treble, and you will notice the difference in the vibrations.

You can also get the same sensation of vibrations on your fingers in another way. Strike a *thin* tumbler (Can you tell why a thick one will not do it?) a light blow with a pencil. Then touch your finger to the rim.

Scientists know exactly how many vibrations per second are given by any string on the piano if they know to what pitch the piano has been tuned. There are three well-known pitches: concert pitch, French pitch, and international pitch. Concert pitch is the highest of these, and the strings of a piano tuned to that pitch are tighter than when any other is used; for the tighter the string, the more vibrations per second. And the more vibrations per second, the higher will be the tone. Sing a low note and press your fingers on your throat. The vibration of the larynx (due to vibrating vocal cords) can be felt. The vocal cords are two short ligaments in the larynx that are tightened and shortened or loosened and lengthened for high or low notes. You cannot see or feel either the ligaments or the muscles that operate them, for all these are enclosed in the larynx.

The Sonometer and Tone Experiments

Buy two cheap violin *D* strings and two wooden violin pegs. Cut a piece of board about eighteen inches long and four and a half wide. Make three little wooden blocks as shown in Figure 29. The one at the left, of hard wood, is four and a half inches by one inch by three-quarters of an inch. Glue and

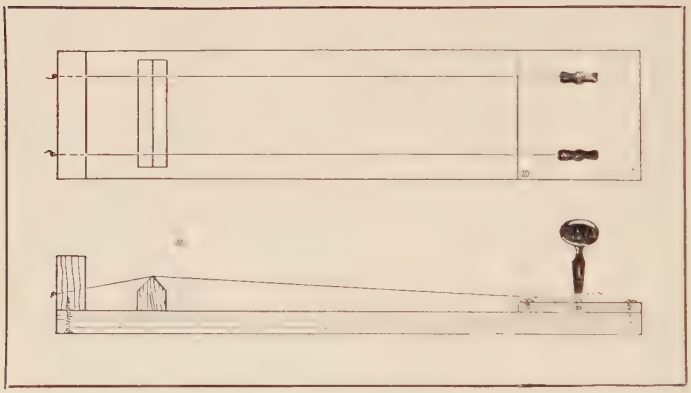


FIGURE 29. A simple sonometer.

screw it in place, and saw two slots for the strings. The middle block is three inches long and three-quarters of an inch square. It is not fastened, but left so that it can be slid back and forth. It is shaped like the roof of a house, and across the ridgepole are cut two shallow slots for the strings to rest in. The block at the right is four and a half inches by one and a half inches, and any thickness from one-quarter to one-half an inch. It is screwed to the baseboard, and has

two holes bored in it for the pegs. These holes should be bored a trifle smaller than the peg, which should be forced in, until it fits very snugly. A bit of soap on the side of the peg will help to get it in place. Tie a large knot in one end of each string and lay the strings through the hardwood block. Wind the other ends several times around the pegs, set the bridge block (that is, the sliding block) in place, and tighten the strings by turning the pegs. Now your sonometer is ready to experiment with.

Pluck one of the strings and listen to the tone. Turn the peg back a little, thus loosening the string, and pluck again. The tone has gone down. Now tighten the string and test to see if it has gone up. You can make the tone go higher without tightening the string. This you can do by shortening the string. Prove this by sliding the bridge-block along. The shorter the string, the higher the tone.

If we have two strings near each other and make one of them sound, the other will sound, too, even though we do not touch it. Pluck one string on your sonometer, and listen carefully with your ear close to the other string. You will hear it vibrate. The sound of the sonometer is weak because there is no resonating cavity or air space under it, so the sound of the untouched string will be very faint. But you can show plainly that it is vibrating. Cut a little piece of paper shaped like a Y with a short leg, and hang it on the second string. Now pluck the first string, and you will see your little rider vault off as if a bronco had

thrown him! It was the vibration of the second string that threw him off. This kind of vibration is called sympathetic vibration.

We should have a great deal of trouble with sympathetic vibration in a piano where there are so many strings side by side, if it were not for the system of dampers. These dampers are little pads of felt, one for each string. They lie against the string to keep it from continuing to sound after the key has been struck. But if you *want* the note to continue to sound, you can lift these dampers off the strings by putting your foot on the damper pedal, wrongly called the "loud pedal."

We found how light is reflected from bright surfaces. Sound can be reflected, too. Reflected sound is called an echo. As the rays of light were thrown back from the mirror so are the sounds thrown back from a wall or cliff face. To get a good echo, one must be one hundred feet or more from the reflecting surface. There is a place in the White Mountains, called Echo Lake, where there is a tall cliff on the farther side of a small lake. To a person standing on the near side of the lake and speaking toward the cliff the echo is very plain. There is also a cave room in the Mammoth Cave in Kentucky where the curve of the roof makes wonderful echoes. If one should sing a chord, for instance, *do, mi, sol, do,* one would hear the chord as if the four notes had been sung all at once instead of separately.

The working of the phonograph depends upon vibration. In making a record the musician, a singer,

for instance, sings into a machine where a sharp needle rests on a turning plate. The plate is entirely smooth at first; but as the musician sings, the vibrations of his voice cause the needle to vibrate, and as it does so, it scratches a tiny groove in the turning disc. Other discs are made from the first one which reproduce every variation of the tiny groove. And when you put a record on the phonograph, you place a needle in the beginning of this groove, which goes through all the motions of vibration that the original needle did, following exactly in the pattern of its path. This gives a reproduction of the original singing.

There is a pretty experiment in sound that you can try with six thin drinking glasses. Stand them in a row, and pour water into them a little at a time, tapping each one with a pencil to test its tone. As you pour water in, the tone goes down, because the vibrating mass (the glass plus the water) is increased. If the tone goes too low, pour out a little water. With a few moments' experimenting you can get six consecutive tones of the scale. Now, with your pencil, you can play the old lullaby tune known as "Greenville." With the addition of one more glass for the highest note, you can play "America."

The tuning fork is like the electric light in one respect—when vibrating, it goes so fast that it appears to be still. But you can easily prove that it is in rapid motion. Strike the fork to set it vibrating, and then lower it slowly over a glass *full* of water. The instant the tip of the fork touches the water a fine spray will

fly off on both sides of the glass. It is the little blows of the tines of the fork vibrating to and fro that throw off the water. Now empty the glass, vibrate the tuning fork, and bring it slowly to the edge of the glass, letting it just touch the rim. The fork will ring the glass with a sound like that of an electric bell.

A scientist discovered that if we have a number of rapid little puffs of air, or a number of rapid little blows of some light body, a tone is produced. The slower the puffs, the lower the tone. When we increase the number per second, the tone goes up, just as it does when we increase the tension (tightness) of a string. You can prove this by dragging the edge of a piece of thin cardboard across the teeth of a comb. Here you have a rapid succession of blows of a light body (the cardboard).

Another way is to take a book which has a rough surface, lay it on the table, and scrape your thumbnail across its cover. If you scrape slowly, you hear a low tone. If you scrape quickly, the tone rises. Your nail, snapping from one rough spot to the next, gives a series of quick blows. Insects such as the cricket and katydid make their peculiar songs by rubbing their stiff, thin wings along their hind legs, which are ridged.

If you can get a cogwheel from an old clock, you can make a very good sound machine. Mount the cogwheel as you did the color disc, so that it can be spun around with a string. Then fix a little block of wood at the side of it and fasten a square of thin cardboard to it so

that the teeth of the cogwheel will strike it as they turn. Use a long string. Pull slowly at first, and the tone will be low. Then pull the string faster, and you will hear the tone rise in pitch, for the teeth come around faster, and increase the number of blows per second.

If you can get an organ reed, you can see how the puffs of air work. Any piano tuner will give you one for the asking. The reed is a small piece of metal with an oblong hole in the middle. In the hole is fastened a very thin metal strip which is a trifle smaller than the hole. The strip is fastened at one end, like your vibration stick, and the stiffness of the metal makes it act like a spring. When the bellows in the organ sends the current of air against the reed, the air shoots past the thin strip, pushing it to one side. But the springiness of the metal brings it back again to where it was before the air struck it. This return of the strip cuts off the air. The pressure of the wind now drives the reed aside again. And so the process is repeated over and over, and we get a series of rapid little puffs of air, making a tone.

List of Words

vibrate	Eustachian tube	phonograph
bass	muscle	music
sympathetic	vibration	throat
hammer	vocal cords	focused
echo	stirrup	anvil
particle	treble	sonometer

CHEMISTRY

WITHOUT a laboratory and expensive apparatus one cannot learn much about chemistry. But a few simple things can be learned about it, and these are important and well worth knowing. First, we must know about the elements. An element is a substance that cannot be broken up into other substances. There are ninety-two elements. Some of them are not very important. Some are extremely rare. About one dozen of these elements form ninety-nine one-hundredths of the earth's surface. The most important elements are: carbon, iodine, chlorine, hydrogen, oxygen, nitrogen, sulphur, arsenic, phosphorus, and the pure metals.

The metals are a large group by themselves, and are divided into two classes, the precious and the commercial. Arranged in outline form, they are as follows:

METALS	*Precious*	gold	platinum	
		silver	radium and others	
	Commercial	lead	mercury	magnesium
		tin	nickel	antimony
		iron	zinc	calcium
		copper	tungsten	bismuth
		aluminum	cadmium	chromium
		sodium	cobalt	and others

There are a few other metals such as brass, bronze, pewter, etc., which are not elements, but mixtures of two or more metals.

Chlorine

This element is very abundant in the earth. If we mix it with one of the metals, sodium, we get common salt. The chemical name of salt is sodium chloride.

Carbon

Soot, coke, charcoal, graphite, and the diamond are *free* carbon. It is hard to believe that the brilliant and beautiful diamond is made up of the same substance that does the writing in the point of your pencil; but so it is. The crystal of the diamond was formed by terrific pressure combined with very great heat. Both were often present when the crust of the earth was wrinkling and folding, and scientists say that diamonds were formed in the crust then. An attempt to form them artificially has been made by subjecting carbon to tremendous heat and pressure. Very minute diamonds—microscopic, in fact—rewarded this experiment. But it is not possible, with such apparatus as men now possess, to get enough heat and pressure to form salable diamonds. One valuable result of the diamond-making experiment was the discovery of carborundum. This is the hardest known substance except the diamond, and is used for grindstones, emery wheels, whetstones, and whenever a

good abrasive (grinding material) is needed. Sugar contains carbon combined with hydrogen and oxygen. Compare it with the free carbon on the end of a burnt match. They do not look alike, do they?

Hydrogen

Two volumes of hydrogen combined with one volume of oxygen form water. Hydrogen gas was formerly used to fill balloons; but a better gas (helium) has recently been discovered. Sound waves will not carry well across a space filled with hydrogen gas. This fact was discovered by a professional balloonist who stepped inside his balloon one time when it was being filled with hydrogen. He called at the top of his voice to his wife, who stood only a few feet away from him, but she heard no sound.

Oxygen

The air is one part oxygen and four parts nitrogen. Oxygen is what we breathe in order to live. If oxygen is so good for us, why is not the air *all* oxygen? The nitrogen is necessary to hold burning in check. If the air were all oxygen, and a fire should start, men could never put it out. After oxygen has gone through the human lungs, it comes out combined with carbon, and we call it carbonic acid gas. Just as *we* need oxygen to live on, so do all plants need carbonic acid gas. They breathe in what we breathe out.

But plants breathe *out* oxygen. So we breathe in

what they breathe out. This is a fortunate arrangement, and is one of the reasons why it is a good thing to have plants growing around us.

A flame, like the human body, lives on oxygen, and will die very quickly without it. You can prove this statement with a glass and a short piece of candle. Light the candle, and turn the glass upside down over it. The flame will burn as long as there is any oxygen in the glass; but as soon as the oxygen is used up the flame will go out. After you have made this experiment can you explain why a fire in the hold of a ship burns so slowly? Why does a fireman wrap his coat around a person whose clothes have caught fire? If a lighted lamp should fall from a table, what would be the best way to prevent a fire?

Sulphur

This element used to be one of the important substances in making gunpowder, but it is no longer used so extensively for this purpose. It was also used in making matches, but is not now. Its chief use to-day is in the making of sulphuric acid and of rubber. It is also a disinfectant. A sulphur candle burned in a room where there has been a contagious disease kills the germs in the room.

Now you have been told a very, very little about a few of the elements. Here are the elements which form some of the common everyday things:—

Hair—carbon, hydrogen, oxygen, sulphur, and nitrogen.

Sugar—carbon, hydrogen and oxygen.

Air—oxygen and nitrogen. (A mixture)

Water—oxygen and hydrogen.

Steel—iron and carbon.

Wood—carbon, oxygen, nitrogen, and hydrogen.

Human flesh—carbon, hydrogen, oxygen, sulphur, nitrogen, phosphorus, calcium, sodium, potassium, and magnesium.

Beefsteak—in the fat, carbon, hydrogen, and oxygen; in the lean, carbon, hydrogen, oxygen, nitrogen, and sulphur.

Butter—this is the fat from milk. Make out its composition from this table.

Sometimes water has other things in it besides oxygen and hydrogen, but these do not belong to the water, and are called impurities. Water which has risen to the sky in the form of water-vapor, is pure because, when it rises, it has to leave behind all solid matter and impurities. Water can take a great many forms. It may be an invisible gas (steam), a visible liquid (cloud, fog, dew, or rain) or a visible solid (snow, ice, or hoarfrost).

Chemical Experiments

1. *Metal and acid.* Take any small scrap of copper and thoroughly clean the surface with a little mixed salt and vinegar, afterward washing it in clean water. Let a few drops of paraffin fall on it from a burning candle. Pour some diluted nitric acid into a shallow china or glass dish, and put the copper in the liquid.

The metal will be burned away wherever it is not covered and protected by the wax; but under the wax it will be left "in relief," as artists say—that is, standing up. The nitric acid can be bought from any drug store. There are two kinds, the chemically pure, and the commercial. The latter is the cheaper, and is good enough for this experiment. The acid is too strong as you buy it, so it has to be diluted with water. Avoid getting any acid on your hands or clothes, as it burns severely. Have an old cloth handy and some ammonia water. If you spill any acid, wash with water and ammonia immediately. You could use baking soda or washing soda instead of ammonia to stop the action of the acid. A substance which counteracts an acid is said to be basic. It is necessary to use a glass or china dish, as the acid will crack or destroy most other kinds.

This experiment is much more fun if you can make the "relief" part of the copper in a design, or an initial. But you cannot draw a design easily with the paraffin. You will need some turpentine asphaltum, instead. This is inexpensive, and can be bought wherever paints are sold. It comes in small tin cans, and is thinned out, when necessary, with turpentine. Use it just as you would paint, and put your design on with a small brush. It is better to use it thin, and paint your design over several times. When the pattern is well covered, and no color shows through it from the copper underneath, let it dry for twenty-four hours. Then put it in the acid bath. Just how long you should let it burn is a matter of experience, and will depend

somewhat on how much you want the pattern to stand up, and upon the strength of the acid.

When the copper first goes into the acid, bubbles begin to rise, and a thin, brownish smoke, which has a sharp, choking smell, comes from the dish. You will need to have a window open, so as to let in plenty of fresh air. When the burning is finished (probably not less than half or three-quarters of an hour) take the dish to the sink, and carefully empty it, copper and all. Do not splash the liquid. Let a quantity of water run through the sink, flushing it out, and washing off the copper.

Now you may pick it up in your fingers. Hold it under the tap and thoroughly wash it. When it is clean and has been wiped dry, scrub off the asphaltum with a rag wet with turpentine. You will see the design standing up in relief as if the copper surrounding it had been carved away.

2. *Test for lime.* Chemists tell us that if we put a drop of hydrochloric acid on any natural substance, and bubbles rise from it, there probably is lime in the substance. You can easily try this. Buy five cents' worth of hydrochloric acid at a drug store. Gather together the following substances:—a piece of bone carefully cleaned inside and out, so that there shall be no trace of grease on it; a piece of eggshell; a piece of cement; a stick of chalk; and a piece of marble. Now put one drop of the acid on each specimen and watch the result. The bubbles on the bone form very slowly. On the chalk they come rapidly. The others range be-

tween. What can you guess from this experiment about the amount of lime in each material? Other acids besides hydrochloric acid will attack lime.

You have doubtless seen the little bone spoons that are often used in serving horse-radish. Did you ever see one that had been left in the bottle for a time? If so, you know that it was as limp as a piece of wet cardboard. The acetic acid in the vinegar on the horse-radish dissolved the lime in the bone spoon so that it became limp and useless.

3. *Potassium.* Druggists do not usually keep pure potassium. One must generally secure it from a wholesale chemist. It is highly inflammable, even in the air, and is dangerous to handle and hard to keep, but you will have no trouble with it if you will keep it in a tightly corked bottle covered with kerosene. When you are ready to use it, pour oil and potassium out into a saucer, cut off the piece you want, and quickly put the rest back in the bottle under the oil.

For this experiment fill a large basin nearly full of water. Light a match, and as soon as it blazes up well, thrust it into the water. It goes out. We are accustomed to think that water puts out fire. Yet there are some cases where water actually lights fire; and this is one of them. Now cut off a very small piece of your potassium, and throw it into the water. It rushes around on the surface, burning furiously, and giving out a bright purple light. One of the favorite experiments of professional lecturers on chemistry is to fire off a small cannon by touching the charge with

a piece of ice. In this case the cannon is not loaded with gunpowder, but with a chemical which explodes when it comes in contact with water.

4. *Iodine.* This element is familiar to most students as a dark brown solution which we put on cuts to kill germs, and on bruises and sprains to keep them from getting sore. In this form, it is *tincture* of iodine. Iodine is extracted from seaweed. The iodine for this experiment is crystal, or "resublimed" iodine. You will need about a teaspoonful of these iodine crystals, and a small test tube. Take up a little of the crystallized iodine on the blade of a knife and put it into the test tube. Now light a burner on the gas stove, turn it low, and hold the bottom of the test tube in the flame. The iodine crystals will give off a beautiful purple vapor, which you can see still better if you will hold the tube towards the light.

5. *Chemical combination.* When we experimented with dissolving, we found that we could get back the salt from the mixed salt and water. The salt and water were only *mixed.* But when substances are chemically *combined,* we cannot get them back. They no longer exist; they have turned into something else entirely different from what they were before. You can prove this with a little sulphuric acid and sugar. Get an ounce of the acid from any drug store. One ounce is enough. Put two teaspoonfuls of sugar in a jelly glass (do not use a good glass, for you might crack it) and pour on it enough acid to make it moist. Nothing will happen for several minutes, but watch it,

and think what the two things you are using look like. The sugar is a white crystalline substance. The acid is a liquid which looks much like dirty water.

In about two minutes the mass in the glass will begin to bubble. Feel of the glass. It is hot. Now the substance is getting darker and darker. It boils up the sides of the glass, and turns black. Let it stand until it is cool, and you can lift it out of the glass in the form of a little black biscuit. Here is a new substance, different from either the sugar or the acid. We cannot get either back. Hold the biscuit in two pieces of paper so as not to get any of it on your fingers, and break it in two. It looks like a sponge inside. It is chiefly carbon.

In the explosion chamber of a cartridge, the several chemicals that make up gunpowder are *mixed,* only. But when the cartridge is ignited by the blow of the hammer, these things *combine.* One of the new things formed by the combination is a highly expansive gas. It is the expanding of this gas that drives out the bullet. The force of the drive is so great that in a good modern rifle, with a good grade of powder, the bullet will fly two thousand yards.

6. *Secret writing.* This is great fun to do by yourself; but it is more fun to "spring it" on some of your friends! Get a little sulphate of iron. As the name shows you, this substance is a compound of the two elements, sulphur and iron. Take a good sized pinch of the granules (tiny round lumps) and dissolve them in about two tablespoonfuls of water. This is the "ink."

Now take a new pen point, dip it in the liquid, and write on a blank sheet of paper. When dry, the writing is invisible. Since secret writing is often associated with buried treasure, you might write something like this:—"United States of America, longitude, 87 degrees, 10 minutes, 3 seconds; latitude, 38 degrees, 4 minutes, 22 seconds (roughly speaking, this is the region of the caves in Kentucky). Set yardstick in hole at left of cave entrance. Drop plumb line from outer end. The treasure is hidden here." Show your friends the sheet on which you have written. They will think it is a blank sheet. Now take an ordinary water-color brush and dip it in what you tell them is a "magic bottle," and paint the sheet all over. The writing will become visible.

Here are the directions for preparing the liquid in the "magic bottle." Get a small quantity of prussiate of potash, or potassium ferricyanide (it is a poison), as it is sometimes called. It is in the form of little red crystals. Put two or three of these crystals into half a teacup of water, pour the whole into a small bottle, cork, and shake well for some time. This is the liquid that will make the writing show plainly.

Here is another way to make secret writing that will appear and disappear at will. The "ink" is made of chloride of cobalt. This chemical is in the form of small garnet-colored crystals. Take one level teaspoonful of the crystals and dissolve them in eight teaspoonfuls of water. Shake them in a bottle until thoroughly dissolved. You will have a red liquid.

Write with a new pen point. A quill is best, but a steel point will work. When this writing is dry it is invisible. The writing is made to appear by heating the paper. Only slight heat is necessary. When the paper cools, the writing fades and disappears. It disappears more slowly than it appears, but if given time enough to cool thoroughly, it fades entirely away. This effect will last indefinitely. If the writing does not entirely disappear after the first heating and cooling it means that you need to add a little more water to the "ink."

List of Words

chemistry
gunpowder
iodine
aluminum
Bermuda
cartridge
nitrogen
potassium
impurities
diluted
balloon
rifle
laboratory
element
precious
invisible
asphaltum
sulphur
phosphorus
cistern
turpentine
helium
chlorine
metal
platinum
disinfectant
nitric acid
combined
calcium
contagious
hoarfrost
explosion
bubble
hydrogen
chloride of cobalt
carbon
sulphuric acid
iron
cloud
carborundum
chalk
oxygen
prussiate of potash
lead
hydrochloric acid
copper
lime
carbonic acid gas
rubber
sodium
sulphate of iron

CRYSTALS

THE study of crystals is a science called crystallography. No one knows what causes the behavior of crystals. It is very curious and mysterious. Any substance that crystallizes has its own particular form of crystal. Some of the forms are simple, like the cube, and some are complicated and beautiful, like the six-sided figure of snow crystals. Some substances crystallize in the form of a pyramid, and some in hexagonal prisms. "Rock candy" is made up of crystals of sugar. Some of the precious stones are crystals in their natural forms; for instance, the diamond, ruby, sapphire, emerald, topaz, and amethyst. If you ever saw any bichromate of potash, you know that it forms in orange-colored cubes. Some of the many forms of crystals are shown in Figure 30.

The best way to learn about crystals, however, is to make some yourself. Since alum is a cheap material which crystallizes, you can use that. For this experiment you need three ounces of powdered alum, which can be bought at any drug store. Put a pint of water in a pan on the stove and bring it to a boil. When it boils, stir in the powdered alum, and boil the mixture for a few moments. While this is boiling, you can make a very good filter out of a piece of clean blotting paper.

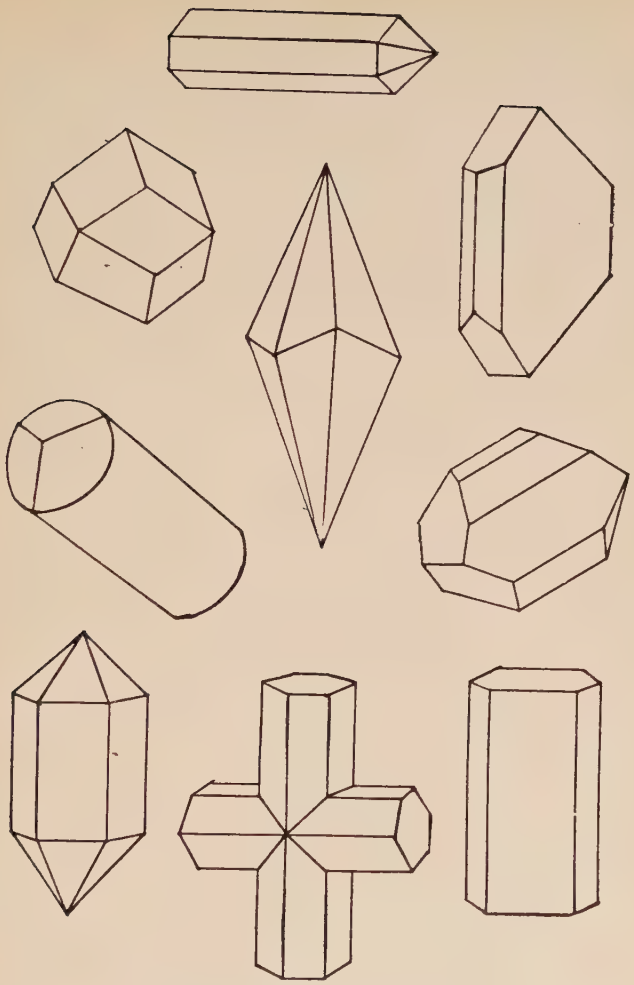


FIGURE 30. Forms of crystals.

Cut out a circle and fold it in the middle once. This makes a half circle. Now fold the half circle in the middle. When you open up this circle, you will have a cone-shaped container with three thicknesses of the blotter on one side, and one thickness on the other. The circle must be large enough so that the filter will sit in the mouth of the jar you intend to use. A pint fruit jar is convenient. Now take the alum off the

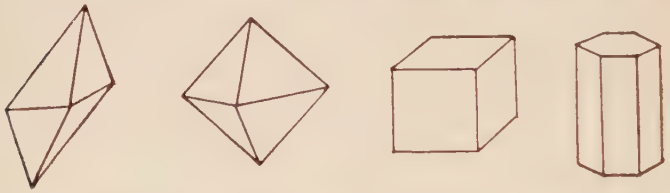


FIGURE 31. Borax crystallizes like A. Alum and diamonds crystallize like B. Salt and gold crystallize like C. Arsenic crystallizes like D.

stove and pour the liquid slowly and carefully through your filter into the jar. Alum makes a white crystal. If you want colored crystals, you can add a little dye to the liquid just before filtering. Now set the jar away to cool, and if convenient, tap it gently once in a while with a pencil. The slight vibration helps the crystals to form, but they will form anyway, whether you tap the jar or not. Their formation takes several hours. A good way to work the experiment is to pour the liquid into the jar at night; next morning the crystals will have formed. (See Figure 31.)

A much prettier effect may be obtained by weaving a little basket of rough string, or wire covered with

cotton. (Do not use silk.) If you let the basket down into the liquid by a string and allow it to hang there while the crystals are forming you will have a beautiful ornamental basket. The crystals like the fiber of the string or coating of the wire to cling to, and will cover it all over. You can get another pretty effect by using a piece of coke instead of the basket. The crystals like its rough surface, and will cover it over until it looks like rock crystals. Wash the coke and get it as clean as possible before using. A great many substances, when heated and allowed to cool slowly, will crystallize.

Which will take up the more room—a heap of sand weighing one hundred pounds, or a heap of coal of the same weight? The coal; because the pieces of coal are so large that they cannot lie close together like the grains of sand, and there are spaces between them. For the same reason, the crystals of alum could not be put back into the box which was just big enough to hold the powder. There are spaces between the crystals. Any substance takes up more room after it has crystallized.

You have all seen paraffin melted and poured over the tops of jelly glasses. The paraffin, in this case, is a substance heated and allowed to cool slowly. Has it crystallized? No. How can we tell that it has not? It has shrunk in cooling and takes up less room than before. You already know that most metals shrink when cooled. It is a law of physics that nearly all things shrink when they cool. How, then, can we ac-

count for the bursting of water pipes when the water in them freezes? When water freezes it crystallizes, and so takes up more room than before.

List of Words

crystal
crystallize
crystallography
hexagonal prism
coke
freeze
cube
bichromate of potash
alum
physics
filter
burst

THE CANDLE

LOOK at a piece of candle that has been burned until there is a depression at the top. What do you notice about the shape of the wick? You can see that it curves to one side. One of the threads of the wick is purposely woven tighter than the others in order to make the wick curl over in this way. Can you guess why? In seeking an answer to this question, light a match and hold it straight up and down. Now light another and hold it slanting. In which position does it burn better? The end of the wick burns off and this saves cutting or snuffing. Some very fine candles are made of wax, but most candles nowadays are made of paraffin. You will remember, in your study of distillation, that you found out where paraffin comes from.

Light the candle and watch it a moment as it warms up. You will see that the little saucer-like depression at the top fills with melted paraffin. We know that the melted paraffin must get up the wick to reach the flame. But can a liquid run uphill? Try a little experiment to see if that can be so.

Dip the end of a stick of chalk (if the stick has a dressing on the outside, scrape it off with a knife) into some ink. You will be surprised to see how the black fluid climbs up the stick. It is by capillary at-

traction, as scientists call it, that the ink goes up the stick of chalk; and it is by capillary attraction that hot paraffin goes up the wick of a candle. Later on in this book we shall meet capillary attraction again. When the melted paraffin gets to the flame it turns to gas. In a burning candle, we have a solid, a liquid, and a gas. Everything in the world is one of these three; so in the burning candle we have the three states of matter in which all the substances of our earth are to be found.

Make a little sketch in your notebook of the flame of the candle. It has three layers—the top, or yellow layer, the middle, or blue layer, and a colorless layer at the bottom. The yellow part is gas heated very hot. From it come the light and the soot. In the blue layer, all the material is burned up. The colorless space is a space full of gas. There is no air in the gas, and it is not so hot there as in the colored parts of the flame. You can prove this last statement by taking a fresh match and passing it quickly into the gas space. It will not light at once as it would if you had passed it into the flame. Use an ordinary match for this experiment, and not a safety match. (See Figure 32.)

If there really is gas in the bottom layer, we ought to be able to pipe it away from the gas space and light it outside the flame. Take three or four inches of small glass tube (or the stem of a broken clay pipe) and hold it at an angle of forty-five degrees (half a right angle), with the lower end in the gas space. Touch a lighted

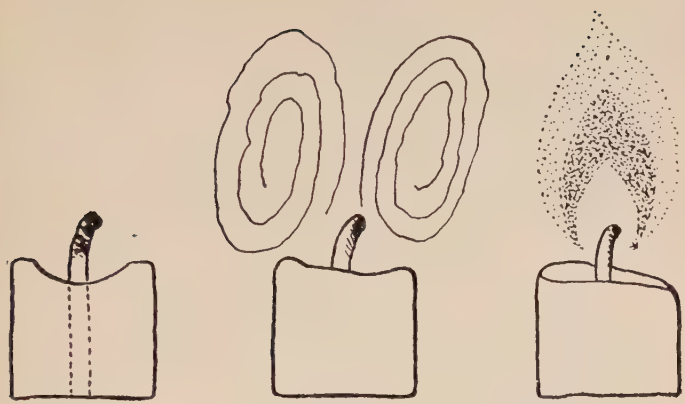


FIGURE 32. A—Cross section of a candle showing the saucer-like depression at the top and the curved wick. B—Diagram showing how currents of air carry the smoke from the extinguished candle. C—The parts of a candle flame. Nearest the wick is the gas space, above it is the blue part of the flame, and outside the blue flame is the yellow layer of flame.

match to the outer end, and the gas will light there. If you do not succeed with this experiment at once, do not give up. In performing it, there are several things about which you need to be careful. The hole through the tube ought not to be more than three-sixteenths of an inch in diameter. The tube (or pipestem) ought to be held in pliers and heated hot first, so that the gas in going through the length of the tube will not be cooled. To do this, pass it back and forth through the flame for several minutes. The tube should not be more than four inches long.

Have you ever noticed the black sticks which the lamp-tender throws out of arc lights? These sticks,

although somewhat scratchy, will write like a pencil. The black substance of which they are made is carbon. As you look at the white candle it is hard to believe that there is carbon in it. But you can prove that there is. The carbon does not show in the flame as long as it burns steadily and there is plenty of fresh air. But if we disturb the flame, and hinder the burning, we can discover the carbon.

Pass a sheet of white cardboard back and forth through the flame several times and then look at the under side of it. It is black with carbon. Just waving the candle about will disturb the flame enough to make the carbon show. You can see it in a little cloud streaming behind the flame. When the flame burns steadily, the carbon is all burned up, but when we interfere with the burning, some pieces of carbon escape. You will remember that in your study of chemistry you learned that carbon is one of the important elements, and that the material in the point of your pencil (graphite) is a form of carbon, as is also the diamond. If it is hard for you to believe that the black material on the bottom of your sheet of cardboard is any relation to a diamond, just remember that although steam does not look much like ice, both are forms of water.

After we blow out the candle, the gas goes on rising for several seconds. Blow out your candle and re-light it with a burning match, without touching the wick. Try this several times until you find out the limit of space over which the flame will jump from the match

to the wick. This space will necessarily be small, because the gas scatters out from the candle in every direction. If we could make it go up in a single small column, the flame would jump much farther.

If you can secure some glass tubing you can prove this. You will need a piece measuring five-eighths of

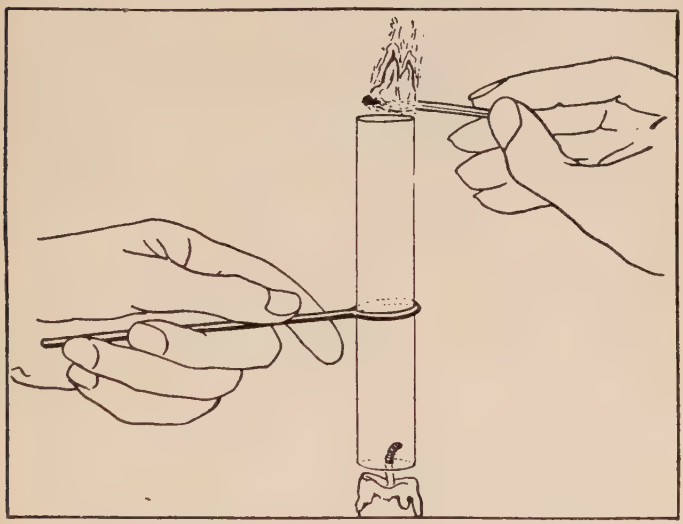


FIGURE 33. Experiment to show how a flame will jump from lighted match to candle wick by means of gas rising from extinguished candle.

an inch, inside diameter, and about five inches long. Hold this tube with pliers, and heat it over its entire length by passing it back and forth through the flame. Now put out the candle flame and lower this tube in a vertical position until its lower end is just above the

wick. Hold a lighted match to the top where the gas is flowing out, and the flame will leap down the five inches to the wick and light it. (See Figure 33.)

This experiment calls for some practice and skill. If you pinch out the flame with moistened thumb and finger it will scatter the gas less than if you blow it out. Get the tube in place as quickly as you can after the flame has been put out. When the flame jumps to the wick it makes a little popping sound. Now we have proved that the candle is a small gas factory. The gas cannot begin to flow until heat melts the paraffin a little, and that is why the candle lights at first rather slowly. The wick is stiff with cold paraffin, and we have to wait until the heat of the burning match melts this.

If you have seen a kerosene lamp lighted, you must have noticed that the chimney was covered at first with a very thin mist that quickly disappeared, beginning at the top and shrinking down to the bottom. The mist is formed of vapor which comes from the burning of the flame in the lamp. It is hard to believe that one of the things a burning flame gives off is water vapor, but it is true. Your candle will show you this vapor, too. Hold a cool, dry glass over the flame for a moment, and you will see the same little mist on the glass. Since the glass is cool, the water rising from the flame condenses on it and shows as long as the glass stays cool. This is not very long, for the heat of the flame soon warms it, and then the water vapor disappears.

From a piece of soft pine wood whittle a few splinters about five inches long and very thin. Light one in your candle, turn a clean glass upside down, and put the burning splinter upright inside it. It continues to burn, and nothing happens. Hold the glass several seconds above the burning candle, and again put the splinter into it. This time the flame goes out as if it had been put into water. The glass has collected some of the gas from the burning candle, and this gas smothers the flame on the splinter. The name of the smothering gas is carbon dioxide. It is the very same gas that makes the bubbles in soda water.

Light a short piece of candle having a very long wick. Turn a glass over it. The flame burns for a moment, then goes out. You can tell why it goes out, and also why it burns for a moment before going out. Repeat the experiment, and this time notice especially the way in which the smoke rises and falls. In your notebook make a little diagram of the motion of the smoke. The smoke shows how the currents of air in the glass move. As we shall find out when we come to learn about the weather, this is the way the currents of air move at the earth's equator.

List of Words

capillary attraction
gas
liquid
colorless
graphite
chimney
thread
saucer-like
solid
soot
moisture
carbon dioxide

THE PROPERTIES OF MATTER

EVERYTHING that we can think of is divided into classes—mind and matter. The study of mind is called psychology, and is too hard a subject for you now. All your studies, therefore, have been about matter. Matter is anything that you can see, touch, handle, and experiment with. As scientists say, matter is anything that takes up space. When we speak of the properties of a thing we mean its own special qualities that always belong to it. For instance, the properties of maple syrup are that it is a liquid, that it has a pleasant odor, that it is golden-colored, that it tastes sweet, etc. The properties of a snowball are that it is round like a sphere, that it feels cold, that it is white, that it will melt, that it can be pressed together and made smaller and harder, etc. Some of the properties of matter have long, difficult names, but if you cannot remember these words, at least you will recognize them when you meet them in books, and you can easily understand the experiments that show them. Here are their names:

in-er-ti-a
in-de-struct-i-bil-i-ty
im-pen-e-tra-bil-i-ty
po-ros-i-ty
com-press-i-bil-i-ty
duc-til-i-ty
mal-le-a-bil-i-ty
te-nac-i-ty
ad-he-sion
co-he-sion

e-las-tic-i-ty cap-il-lar-i-ty
brit-tle-ness os-mo-sis

Compressibility and elasticity go together, because they are the two halves of the same thing. They are twins, so to speak.

Inertia

Anything at rest tends to stay at rest. Anything in motion tends to keep on moving. If a person steps off a moving car, it seems as if some one were pushing him in the direction in which the car is moving. When on a car, we move with it. When we step off, we tend to keep on moving. If the car is going fast when we get off, we cannot help running when our feet touch the ground. This, however, is not an experiment for you to try; it is dangerous to step off a moving car. It is easier to run forwards than to run backwards (as you can prove by trying, if you want to!) and this is the reason why on cars are signs reading, "Face forward when alighting." Anyone getting off backwards from a moving car is likely to have a violent fall.

An inexperienced horseback rider sometimes has a startling illustration of inertia. Some horses, especially the western cow ponies, are very skillful at stopping suddenly. When the horse stops, the unaccustomed rider experiences the working of inertia and keeps on going, with the usual result that he is thrown over the horse's head, and falls to the ground!

There is an easy experiment that you can try to prove the working of inertia. Place a visiting card

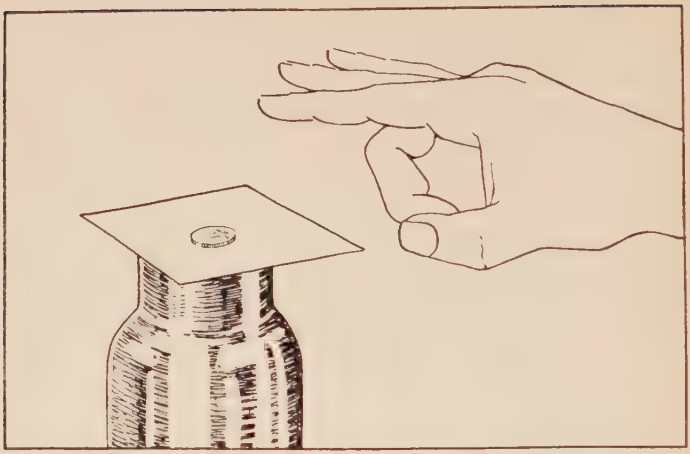


FIGURE 34. Experiment to prove the working of inertia.

across the top of a large-mouthed bottle, such as an olive bottle. In the center of the card lay a penny. You are going to flip the card off the bottle with a snap of the finger. Do you think the penny will go with the card, or not? Now snap the card away. The penny goes jingling down into the bottle. The penny was at rest when you snapped the card, and so it tended to remain at rest. That is why it did not fly off with the card. But of course when the card on which it rested went out from under it, it had to fall down into the bottle. It fell because of the pull of gravity. In this experiment you must be careful not to lift the card up, or to drive it down. It is necessary that it go straight out—that is, in a horizontal direction. (See Figure 34.)

Indestructibility

Nothing in the world is ever destroyed; it only changes form. You remember that when you boiled the spoonful of salt water, the water appeared to be destroyed; but it was not. It only turned into steam; that is, water-vapor, and went off into the air of the room. Burn a sheet of paper and watch it. We say it is destroyed. What has become of it? There is a tiny bit of ash left, but where is the rest? If you watch carefully while it is burning you will see thin vapors rising from it and disappearing through the air in the room. A part of the paper is still in the room in the form of gases.

Suppose you jot down in your notebook a little schedule that you might call the life and adventures of a raindrop. Beginning with its fall from the clouds as a drop of water, you can trace it through many changes. It falls upon the earth and is soaked up by the ground, drawn into the roots of a plant, breathed out by the plant as vapor, rises into the sky, forms a cloud, and again falls as rain, etc. This is only one group of adventures among many that might befall a raindrop. When we die, the material of which our bodies are made is not destroyed. It only changes its form into other forms of matter.

Impenetrability

This long word means only that two bodies of matter cannot be in the same place at the same time. For instance, a glass bottle which we would say is empty,

but which is really full of air, cannot be filled with water while the air is in it. The water will not go in unless the air can come out. You can prove this with a piece of apparatus which you can make yourself; but you will need to get some glass tubing in order to make it. It would be a good plan, when you go to the druggist's for your chemicals, to go to the counter where glass tubing is sold, and ask the clerk if he has any waste glass—short ends cut off from long tubes, or pieces of broken tube. These sell for only a few cents a pound, and you will find them most useful in many of the experiments in this book. Tubing of three-eighths, one quarter, or three-sixteenths inch *inside* diameter is best for your purpose.

Now to get your apparatus ready, you will need to make an L tube—that is, a tube bent in the shape of a capital L. Take a piece of your glass tube about ten inches long, and heat the middle of it in a burner of the gas stove. You will be surprised to see that you can hold the tube in your fingers without feeling the heat. Turn the tube around and around as you heat it, so that all sides get heated. Soon the glass will soften, and very gradually, still keeping the tube in the flame, you can bend it into an L shape. Now take a large bottle with a wide mouth and fit a tight cork to it. With a red-hot nail burn two holes, at least three-quarters of an inch apart, through the cork. Through one hole force one end of the L tube, and in the other put a small funnel. (Figure 35 shows the apparatus completed.)

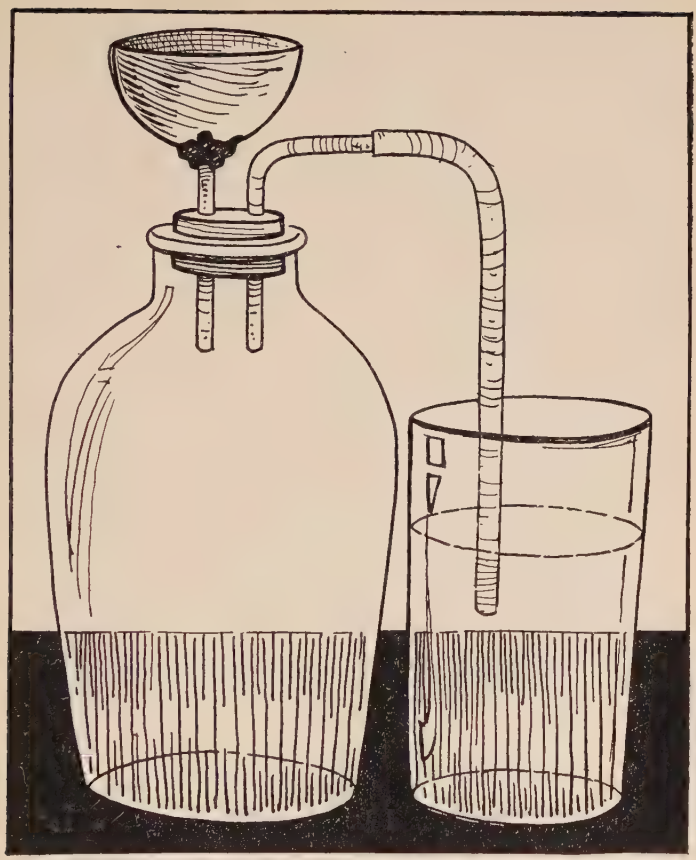


FIGURE 35. Apparatus in experiment to prove impenetrability.

You can make a funnel with the other half of your old tennis ball from which you made a model of the eye. In the bottom of the remaining half bore a hole,

through which put a piece of glass tube. If the funnel leaks when finished, plaster it with a bit of clay. Be sure that the funnel and L tube fit snugly in the cork. Over the outside end of the L tube slip a short piece of rubber tube. (A piece of old syringe tube may be used.) The other end of the rubber tube is to be carried down into a glass nearly full of water. Fill the funnel with water. It will run into the bottle, and the air in the bottle will come out through the L tube. You can see it bubbling up through the water in the glass. Now pinch the tube so that no air can get through it. The water stops running from the funnel. But you may have noticed that several drops ran through the funnel *after* you pinched the rubber tube. That is because the air in the bottle can be compressed a little.

When we throw a stone into a pond, the water has to move aside to make room for the stone, and its level rises, even though the rise may be very small. We say that the stone displaced a certain amount of water. Fill a glass two thirds full of water and lower into it a stone tied to a string. You can tie another string around the glass where the top of the water came at first. The amount that the water rises above the string is the amount of displacement. Do not use too big a stone or the water will overflow, nor too small a stone, as the displacement will be too small to show well. When you have found out the amount of displacement, you will know that that amount of water is what the stone would hold if it were hollow. This

is a way in which the contents of any irregular shaped container can be measured, or the volume of any irregular shaped body found out.

Porosity

All matter is composed of small particles with spaces between them. These spaces are much smaller in some things than in others. When the spaces are

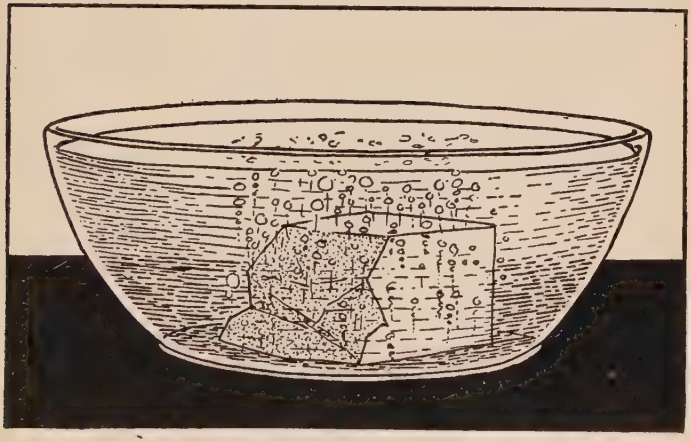


FIGURE 36. Experiment in porosity. Brick is porous. When a brick is placed under water the air comes out of the pores in little bubbles.

small, we say that a thing is dense, and when large, that it is porous. In charcoal, brick, chalk, and wood, the spaces are comparatively large. These spaces, or pores, as they are called, are full of air. You can make an experiment to prove this. Fill a large glass dish with water, and put in it a piece of a brick. You

learned from the bottle with funnel and L tube that if the water goes in, the air must come out. Since the piece of brick is under water, you will be able to see the air coming out of the pores in little streams of bubbles. Repeat this experiment with a stick of chalk, a piece of charcoal, and a block of wood. The charcoal and the wood will have to be held under the water, because they are so light in weight that they will float, if they are not. (See Figure 36.)

Compressibility and Elasticity

As all matter is porous, anything can be compressed. The smaller the pores, the less compression is possible. A bale of cotton is very compressible. When it goes into the cotton press, it is about four feet thick. When it comes out, it is about fifteen inches thick. Air can be compressed a great deal. It is compressed air that works the brakes on a street car or a railroad train. When the pressure tank is opened, the compressed air rushes out and returns to its original denseness. The cotton bale would open up again when the pressure stops, if it were not for the iron bands that hold it. This quality of stretching and returning to the original state is called elasticity.

Rubber is very elastic. Measure a rubber band in its natural state, then stretch it gently, release it, and measure it again. It has not changed. Now stretch it as hard as you can without its breaking. When you measure it this time you will find that it has not quite come back to its original state. Rubber, while very

elastic, is not perfectly so. We know that glass has but little elasticity in any of the forms in which we know it well. But glass can be drawn out into fine threads, like hairs, which, while tough and strong, are elastic enough to be woven into cloth. At the time of the

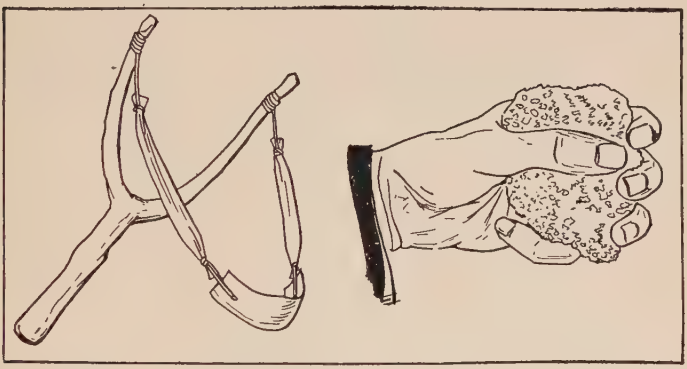


FIGURE 37. A slingshot makes use of elasticity. A sponge has great compressibility.

Columbian Exposition in Chicago, a glass company made an evening gown for the Princess Eulalia which was woven of glass threads.

The elasticity of metals is one of their most valuable qualities. The working of the spring is dependent upon it. When one thinks of the tremendous amount of work done by springs in modern machinery, one realizes that elasticity means much to mechanics. You have noticed how elastic is the blade of a saw. You can bend it far to either side, and it will come back to its original state. But the saw blade is like rubber—while very elastic, it is not perfectly so. Therefore you

should not thrust too hard when sawing, for if you bend the blade too far, it will not come back to its original straightness. It will get a kink in it, which will seriously injure it.

Brittleness

This property of matter is so familiar to every child that it needs no explanation, but you might give it a little space in your notebook, by making a list of things that are noted for their brittleness, such as ice, china, sealing wax, glass, etc.

Hardness

Which of two things is the harder? The one which will scratch the other. When we have found a substance that nothing will scratch, we know that we have found the hardest known substance. Such is

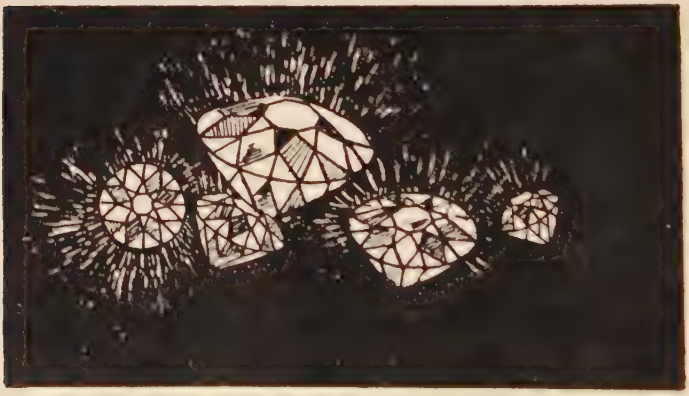


FIGURE 38. The diamond is the hardest known substance.

the diamond. Scientists have arranged a scale of hardness, numbering the substances, which stand for the different degrees of hardness, from one to ten. The higher the number, the harder the substance. We should expect to find the diamond number ten, and so it is. Here is the scale:—

1. talcum
2. gypsum
3. calcite
4. fluorspar
5. apatite
6. orthoclase
7. quartz
8. topaz
9. sapphire
10. diamond

In this scale you will notice that quartz is number seven. If any substance is as hard as quartz, it is said to have a hardness of seven.

Ductility

Mechanics say that a wire which can be drawn out thin without breaking has great ductility. Most metals are very ductile. Even glass has some ductility. You can show the ductility of glass with one of your glass tubes. Light a burner on the gas stove (or alcohol lamp) and heat the middle of a piece of tube as you did in making the L-tube. When the glass gets soft, instead of bending it pull the two ends gently and slowly apart. The tube will get thinner and thinner until it breaks in two, leaving a fine hair of glass on each end. Thus, from this experiment, you see that glass has great ductility.

Turning aside for a moment from the subject of ductility, I should like to tell you what you can make

out of the two pieces of glass tube. If you look closely, you will see that the hole in the tube has been closed at the melted end. Break off, or cut off, the small ends so that the openings will be about one thirty-second of an inch across. On the other ends, put little rubber

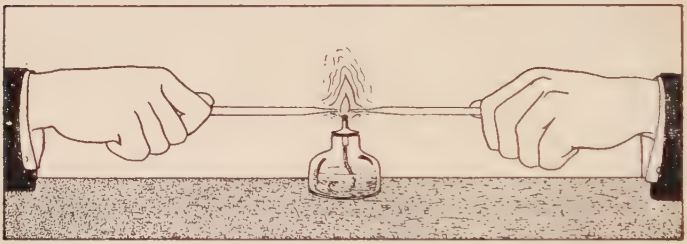


FIGURE 39. Glass has ductility when softened by heat.

bulbs, which you can buy at a drug store. Now you have two excellent medicine droppers, or fountain pen fillers.

The right way to cut a glass tube is as follows:— mark at the place you want to cut, with a piece of wet chalk. File for a moment with a corner of a three-cornered file, and then break. In breaking, hold the tube in both hands, fingers underneath, thumbs on top, one on each side of, and opposite the file mark. Then snap off with a firm, quick pressure.

Malleability

Malleable iron is iron that can be rolled out flat into a thin sheet. Steel can be rolled out as thin as paper. Gold is the most malleable of all metals. It can be rolled out in sheets which are one three-hundred-

thousandth of an inch in thickness—or perhaps one might say, in thinness! This very thin gold is called gold leaf. It is used for lettering signs on the glass of doors and windows, for picture frames, for interior and exterior decorations, and for experimental work in electricity.

Tenacity

Tenacity is resistance to pulling apart. You can show tenacity by a simple experiment. Hold a sheet of tough paper in front of you in both hands. Now try to tear it by moving your hands apart in opposite directions, subjecting the paper to strain in the direction of its length. A sheet of good paper can hardly be torn apart in this way, so great is its tenacity. The poorer the quality of paper, the more easily can it be torn, and the less tenacity it has.

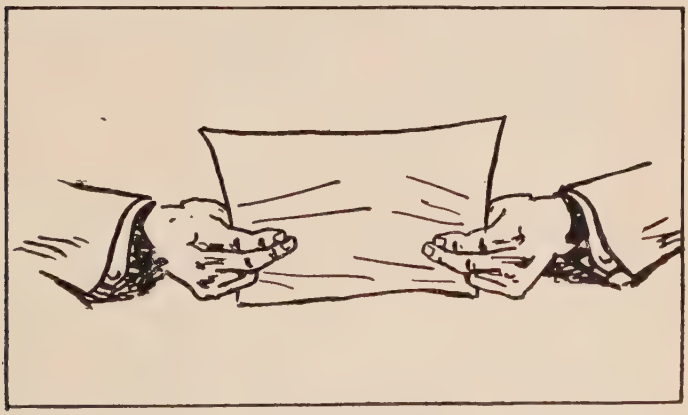


FIGURE 40. Pulling a sheet of paper to test its tenacity.

Gold has a great deal more tenacity than either iron or steel. That is why it holds together even when rolled so thin. Brass has a good deal of tenacity. A brass wire fourteen one-thousandths of an inch in diameter will hold up a weight of twenty pounds. But if one adds even an ounce more than twenty pounds, the wire breaks. Mechanics say that the wire has a breaking strength of twenty pounds.

Adhesion

Fill a glass with water and touch your fingers to the surface of the water. A drop or two will remain hanging on your fingers. This tendency of the drop to cling is called adhesion. If the glass had been full of syrup, more of the liquid would have adhered to the fingers. Glue, in the moist state, has still more adhesion. Perhaps you think that if something with a slippery surface were used to touch the surface of the water, no drop would remain. To test this, dip the end of a candle in the water. You find that the drop remains just the same.

Cohesion

Take a tin pan that has a smooth surface on the bottom and turn it upside down on a table. Oil the bottom thoroughly, and wipe off the oil with a cloth. Now dip one of your glass tubes in a glass of water. The water will go up in the tube, and if you cover the top end with your thumb, water will stay in the tube when you lift it out of the glass. By letting go with

your thumb for just an instant, and putting it back again immediately, you can make the water drip out of the tube, one drop at a time. (This, by the way, is the best method of putting the drops of acid on the different substances in your lime test.) Now put a single drop of water on the bottom of the pan, and an-

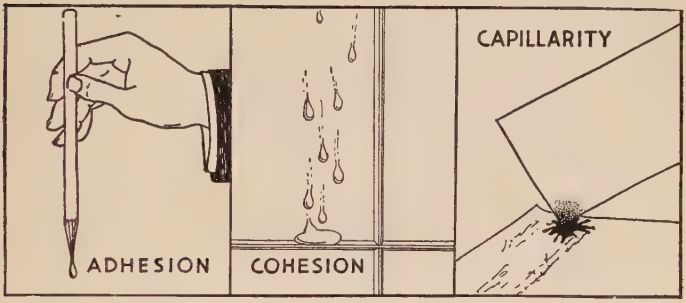


FIGURE 41. The drawing at the left shows a drop of water clinging to the end of a pencil. The center drawing shows drops of water uniting through cohesion, while the right-hand drawing shows a blotter taking up ink because of capillary attraction.

other drop one inch away from it. Push one drop toward the other, using the side of the end of the tube. The instant the two drops touch, they leap together into one drop. The tendency to leap together is called cohesion. This action of the drops can be watched to advantage on a windowpane when it is raining, and on the sides of the bathtub when you are taking a bath. If you do not have the things suggested with which to perform this experiment, use a plate rubbed with butter, and drip the drops off a teaspoon.

Capillarity

You found out in experimenting with the candle that the melted paraffin goes up the wick by capillary attraction. It is as if the little particles part way up the wick said to those at the bottom, when they begin to be wet with the hot paraffin, "Here, give us some of that!" So the bottom particles pass some up to those next above them, and those pass it on again to the next, and so on up. Next time you put a lump of sugar in a cup of coffee, instead of dropping it in, hold it touching the coffee and see the liquid climb up the lump. This is caused by capillary attraction. It is by capillary attraction that the oil in the oil chamber climbs up the wick to the flame in a kerosene lamp. It is by capillarity, also, that a sponge fills with water.

Put a pencil in a glass of water, and hold it upright in the center of the glass. You can see that the water has climbed up the pencil until it is above the level of water in the glass. Now put four different sizes of glass tubes into the glass and see what happens. In the smallest tube, the water climbs the highest. It would be a good idea to put a sketch of this in your notebook.

Osmosis

"Osmosis," says the scientist, "is the tendency of liquids to diffuse through partitions." It may be that you cannot understand what this means; but your mother, if she has ever made a pie out of dried

apples, knows all about it, though she may not know it by these long words. The "partitions" are the coverings of the pieces of apple, and when the apple is being prepared for a pie, it is put to soak in water. You know how tough and hard the pieces are before soaking, and how soft they are after soaking. This action of the water in making its way through the partitions is osmosis.

LIST OF WORDS

compressed	porous	inert	adhere
ductile	brittle	inertia	adhesion
Malleable	elastic	displace	displacement
pores	properties	cohere	cohesion

FORMS OF MATTER

WHEN learning about the candle you were told that all matter is in one of three forms—solid, liquid, or gas. Now you can learn a little about the characteristics of these forms.

In a solid, the particles that make the matter are locked tight together. This holding together is called cohesion. Heat can overcome cohesion, and turn a solid into a liquid, or a liquid into a gas. Paraffin is a solid, and you have seen it turned into a liquid by heat. Water is a liquid, and you have seen it turned into a gas (steam) by heat. It takes a great deal of force, however, to separate the particles when cohesion is holding them locked up in a solid. Another characteristic of solids is that they have a shape of their own.

In a liquid there is some cohesion. The particles are held together, but so loosely that they can roll around and over each other and move about. Liquids do not have any shape of their own, but take the shape of the receptacle into which they are poured.

In gases the cohesion has been overcome by the heat and the particles are moving so rapidly that they do not stick together. The particles are trying so hard to fly off into space in all directions that a gas has no shape of its own.

Air is a mixture of gases. Since gases try to fly off into space, what keeps our atmosphere from leaving

the earth? The answer is that the up-rush of air and the down-pull of gravity are balanced. Another characteristic of gases is that they are transparent. Here is a little schedule that you can copy into your notebook:

FORMS OF MATTER

1. A solid.
   a. Particles held together tightly by cohesion.
   b. Have shapes of their own.
   c. Not transparent.
2. A liquid.
   a. Particles held together loosely by cohesion.
   b. Have no shape of their own.
   c. Not transparent.
3. A gas.
   a. Particles not held together at all.
   b. Have no shape of their own.
   c. Are transparent.

THE AIR

THE air is a mixture of several gases which can be taken apart. The two most important constituents are nitrogen and oxygen. There are also several other gases present in small amounts. Argon, used to fill electric light bulbs; neon, the gas that gives the brilliant red light in the new neon signs; helium, now used instead of hydrogen to fill balloons; and krypton, xenon, and niton—three very rare gases. Their names mean "hidden," "stranger," and "shining." Krypton is the gas that gives the green color to the Northern Lights just as neon gives red in an electric sign. Niton is "shining" because it, like the well-known radium, shines in the dark.

There are also other gases that are found in the atmosphere. Carbon dioxide is a waste product of living things. Water vapor that condenses into rain is present. Ozone—another form of oxygen—the gas that causes the rank odor after thunderstorms—is chiefly found high up in the outer atmosphere where it is formed by the action of sunlight. The air, also, especially near cities, has gases of various sorts that are formed in manufacturing processes. One of the commonest of these is a compound of sulphur. It is this that causes silver to tarnish and turn black.

When iron has lain exposed to the air for some

time, we find that it has combined with the oxygen of the air; that is, it has rusted, or, as the chemist would say, oxidized. Most metals rust, some readily, others less readily. If we heated a metal like iron hot

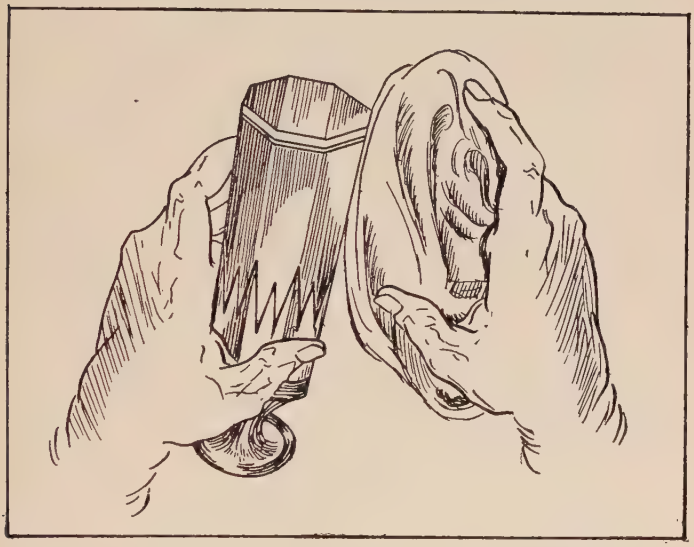


FIGURE 42. Because silver tarnishes it is necessary to clean it often.

enough, the rusting would take place so rapidly and with such vigor that we should say the iron burned.

We can prevent rusting by covering the surface with a rust-resistant material like paint or nickel or chromium plate. Nickel and chromium rust as iron does, but the rust sticks so tightly that no more oxygen can penetrate and the rusting stops when a very thin layer has been formed.

When we paint a surface, we are covering it with an impenetrable layer of rust that is already formed, for the red lead which is in paints is the rust of lead.

Even our own bodies are oxidizing. We are slowly burning all the time. Hold your hands against your cheeks. Do you feel heat? The temperature of the body of every well person is 98⅜° Fahrenheit. When it is 98° by the thermometer out of doors, we think it is pretty hot! I have heard children say that their temperature must have been less after they went in swimming and were cooled off; but that is not so, unless they have become sick. If a doctor should take your temperature just before you go in swimming, when you feel very hot, and again when you come out, feeling nicely cooled off, you would find both readings of the thermometer the same, if you were well.

The air has weight, although it is very slight. This is how a scientist weighs the air: First, he takes an air-tight box full of air, and weighs it on his scales. Then he pumps out all the air in the box with an air pump, and weighs the box again. The difference between the two weighings will give the weight of the air.

The following is a comparison of the weight of air and water:

One cubic foot of air weighs 32 grains.

One cubic foot of water weighs 25,000 grains.

The air in any box weighs about one one-thousandth as much as the water that would fill it.

Air is about one thousand times lighter than water.

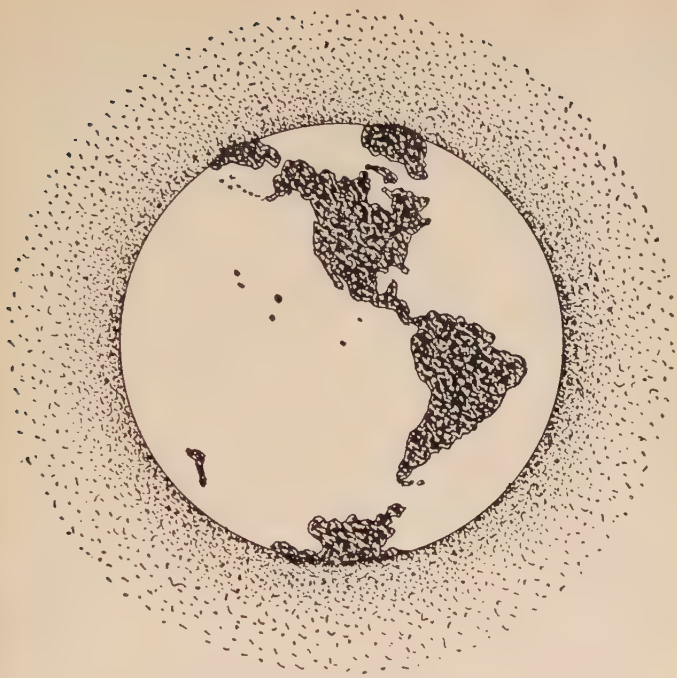


FIGURE 43. Diagram of the earth and its atmosphere, showing that the air is densest nearest the surface of the earth.

If you want to get a good idea of what a cubic foot is, cut down a grocery or drygoods box, so that it is twelve inches long, twelve inches wide, and twelve inches deep, inside dimensions. This box will hold one cubic foot.

The air lies around the earth in a layer at least one hundred miles thick. It is heavier near the earth, but grows lighter as we go up. Next time you get a

chance, look at a big pile of newspapers, say three feet high. The bottom papers are pressed together very tight by the weight of those above, while the top layers lie loose, and are not compressed at all. So it is with the air around the earth. We notice the change in the weight of the air as we climb a mountain. To some people, especially those who are ill, the change in the weight of air is quite distressing. Sometimes they become nauseated, and have nose bleed. Man, unaided by artificial means, can go five miles above the earth, and live. With an oxygen machine to aid in breathing the limit is six miles. A French balloonist who lost control of his balloon, went up a little over five miles, and became unconscious. When his balloon finally came down of itself, he was almost dead, and had a long illness afterward.

Since man can go up only a few miles in the air, how do we know that it is one hundred miles thick? We can get the answer to this question from the astronomers. They tell us that "shooting stars" begin to burn as soon as they come into the earth's atmosphere, and they are able to measure the height of a shooting star at any given moment. These measurements give one hundred miles as the height of the star when it begins to glow, so we know that the air is at least that thick.

Instruments for measuring the pressure of air are called barometers. There are two kinds, the mercurial barometer, a glass tube with mercury in it, and the aneroid barometer. The latter is very complicated. It has no mercury in it, and works by the moving of a

very thin metal disc, a little like the bottom of an oil can. Barometers vary at different levels; as the pressure of the air changes, the barometer reads more or less. All barometers are adjusted to read at sea level. As one goes up, the mercury in the barometer falls. The height of mountains can be obtained in this way.

By the movement of the barometer we are also able to forecast the weather. It is the air movements which have most to do with weather and the changes in pressure which the barometer records. Air descending in a clockwise motion over an area several hundred miles in diameter causes a high pressure and the barometer rises. This is called a "high." Air ascending in a counter-clockwise motion over a like area causes a low pressure. This is called a "low." The wind blows from a "high" to a "low" and ascends laden with moisture which precipitates as rain. The barometer rises with the high pressure and falls with the low. The pressure of the air is on the mercury at the base of the tube, and as it increases it makes the column of mercury go *up* in the tube. When it lessens, the mercury, not being driven up the tube, settles down lower. Thus the weather man knows when it is likely to rain, although there may be no sign of storm in the sky.

The air presses on our bodies with a weight of about fifteen pounds for every square inch. An ordinary sized person, therefore, bears all the time a pressure of about fourteen tons! It is no wonder, then, that we feel tired and languid when the air becomes heavier! Men who go down into caissons (water-

tight chambers) are in an atmosphere much heavier than natural air, and so can work only two or three hours at a time. Then they have to come out and rest before they can go down again.

If you know an organist who has a pressure box in his organ, ask him to take you in there sometime. You will have a curious and interesting experience. There is a vestibule room (sometimes two rooms) into which one must step and wait a few moments till the body can adjust itself to the heavier pressure. You will feel the pressure in your ears, which will have a very full feeling, and may perhaps squeak unpleasantly, when you try to speak. If you will swallow often, your ears soon feel relieved. Now you may enter the main pressure chamber, where you will have the experience repeated; but after a few moments you will get over feeling queer. If you had gone straight from the outside air into the main pressure chamber, you would have run the risk of bursting your ear drums. People with diseased ears, or weak lungs, should not go into a pressure chamber.

Now you will want to know why we are not pressed flat by this air pressure of fourteen tons. The answer is that the pressure is *out* as well as *in*, and *up* as well as *down*. There are four easy experiments by which you can prove this statement.

1. Take a large paper bag and open it out as well as you can by putting your hand down into it and smoothing it out. Put one of your large glass tubes into the mouth of the bag, and gather the paper tightly around

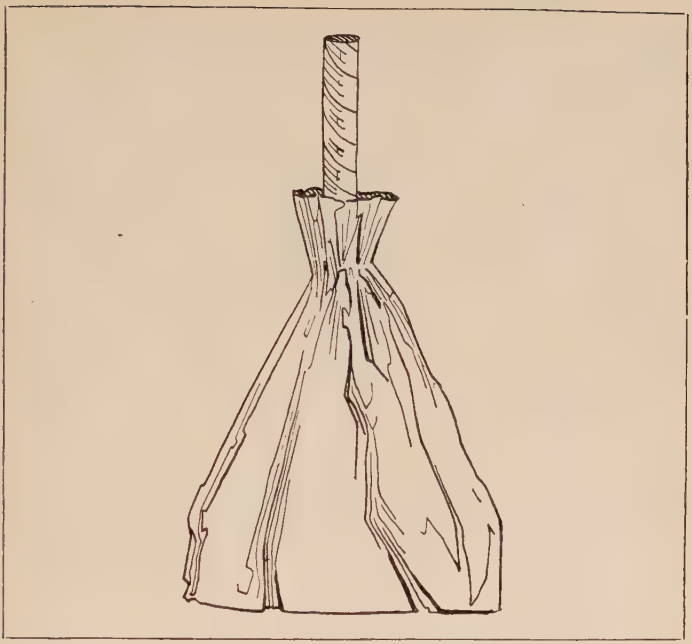


FIGURE 44. A paper bag and paper rolled to form a tube are used to prove air pressure.

the tube, leaving enough of the tube sticking out at the top to put into your mouth. The bag is now like our bodies; the air outside is pressing in, just as much as the air inside is pressing out. Now put the tube in your mouth and begin to suck out the inside air. Do not let any air get in around the neck of the bag where you are holding it gathered up tightly. By sucking out some of the air, the in-pressure and the out-pressure have their balance destroyed. There is

less pressure inside, now, than there is outside; and, as you would expect, the bag begins to cave in. If you keep on sucking, the bag becomes almost flat. If you do not have a glass tube, you can make a tube by twisting up a long narrow strip of stiff paper. This twisted paper tube is the kind that you see in Figure 44.

2. From the top of an old shoe or any available piece of leather, cut out a three-inch circle. Make a small hole through its center with a nail. In one end of a piece of dowel rod about three-eighths or one-half inch in diameter, and a foot long, bore a small hole. Take a small screw, put it through the hole in the leather, and screw it tightly into the end of the dowel. Dowels can be bought at carpenter shops and most hardware stores; but if you have none, you can use, instead, any good strong stick for this experiment. The stick must have a flat, smooth end. Spread the leather out on the table, and lift it up by the stick. Notice how little effort it takes to lift the leather—so little that you cannot notice it at all. There is the same pressure of air *under* the leather that there is *over* it. Now soak the leather in water until it is thoroughly wet through. Spread it out on the table again (a bare table, of course) until it is smooth and flat. By wetting the leather we have made it lie so close to the table that there is no room for air under the leather. Now try to lift the rod. You will be surprised to see how much strength it takes. This is because all the air pressure is on top of the leather, and none underneath.

3. Fill a glass brimful of water, and cover it with a piece of thin cardboard a little larger than the top of the glass. Make sure that the cardboard is in contact with the rim of the glass all around. Holding the cardboard in place with one hand, turn the glass upside down with the other. Hold it so for a moment, while you think what would happen if you should take away the hand that holds the cardboard in place. The glass of water is heavy. Will it not push the cardboard away and spill out on the floor? Take away your hand and see. Instead of falling off and letting the water out, the cardboard remains in place. The glass is so full that there is no room for air in it, so the pressure is all on the outside, pressing in. Therefore the air pressure on the cardboard holds it in place.

4. For this experiment, buy a U tube if you can. You can get it where you got your glass tubes, and it costs only ten or fifteen cents. If you cannot get one, make one by heating one of your tubes and bending it in the shape of a capital U. Pour water into the U tube until it is about half full. Hold it up in front of your eyes. The level of the water is exactly the same in each leg of the U, because the air presses equally on both sides. Now tip the U tube slowly to one side until the water has almost reached the top of the down-side, and cover the end of the tube on the down-side with the end of your thumb. Then hold the tube up vertical again. In the covered end, the column of water remains up. You have prevented the equal pressure of air on both sides, by covering one side with

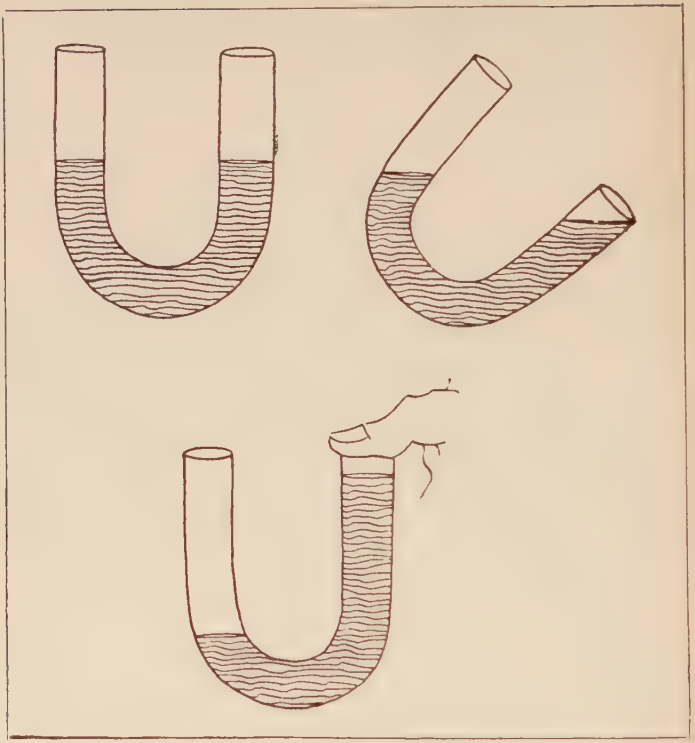


FIGURE 45. A U tube partly filled with water used to prove air pressure

your thumb. Take your thumb off the end of the tube and the water will return where it was before, first swinging back and forth for a moment or two. (See Figure 45.)

Cold air comes down because it is heavier than warm air. Did you ever send up a fire-balloon on Fourth of July night? If so you have already performed an ex-

periment to prove that hot air rises. Why does your teacher tell you to open the schoolroom windows at the top? Air is continually rising and falling and moving about. It is this restless motion of the air that makes the stars seem to twinkle.

Air is, as you have been told, a gas; and like other gases, there are spaces between the little particles that compose it. Therefore, we can crowd it together into less space if we wish. This crowding together is called compression. When you use a bicycle pump, you are compressing the air in the tires. Air does not like to be compressed, and as you already know, if you have ever pumped up bicycle tires, it tries hard to resist the compression.

Fill a basin and a glass with water, and lower the glass right side up into the basin. Do you feel any resistance when the glass goes down into the water? Empty the glass, and lower it again into the basin right side up. How about resistance now? Turn the empty glass upside down and push it down into the basin. Now you are crowding together the air in the glass. The deeper into the water it goes, the less space the air can take up. Now tilt the glass a little to one side so that the compressed air can get out. It rushes up in big bubbles.

When air has been compressed, it always tries to get back to its original state. If you have ever emptied bicycle tires by holding down the valve plunger, you know with what a glad whistle air bursts out of its prison. It makes you think of children rushing out

of school at noon! The best way to show that air returns to its original pressure when it has been compressed, is to make a compressed air fountain.

To Make a Compressed Air Fountain

Put a snug-fitting cork into the mouth of a narrow-necked bottle holding about a pint. With a hot nail burn a hole through this cork into which you can force a piece of three-sixteenth inch glass tube, so that it will fit tightly. Light a burner on the gas stove (or alcohol lamp) and begin to melt one end of the glass tube. Keep turning it slowly round and round so that it will be heated equally on all sides. The end will close up, little by little, but it will be quite a long time before it is small enough for this experiment. Do not entirely close up the hole, but leave an opening about the size of the point of a fine needle. Blow your breath through the tube now and then to see that you have not altogether closed it. If you should close it by accident, then let the tube cool, and gently and carefully file the end a little with the flat side of a wet file. This will open the hole again. After the tube has cooled, push it through the cork. Fill the bottle about one-third full of water, and press in the cork tightly. The end of the tube with the tiny hole is outside the bottle, and the large end inside. You can raise and lower the tube through the cork without taking it out. Lower it until the large end goes down about one inch into the water in the bottle. Your fountain is now ready to be worked. (See Figure 46.)

Set the bottle into a large pan or basin. Cover the tube with your mouth and blow air into the bottle. You can see the air bubbling up through the water in the bottle. When you have forced all the air in your lungs into the bottle, you will need to take another breath, and while doing so, cover the tiny opening of the tube with your tongue so that none of the air you have blown in can get out again. Blow as much air into the bottle as you are able. Now you can take your mouth off the tube; but do it with a quick jerk, or you will get caught in the fountain. The water rises to a surprising height, and the fountain "plays" for several minutes.

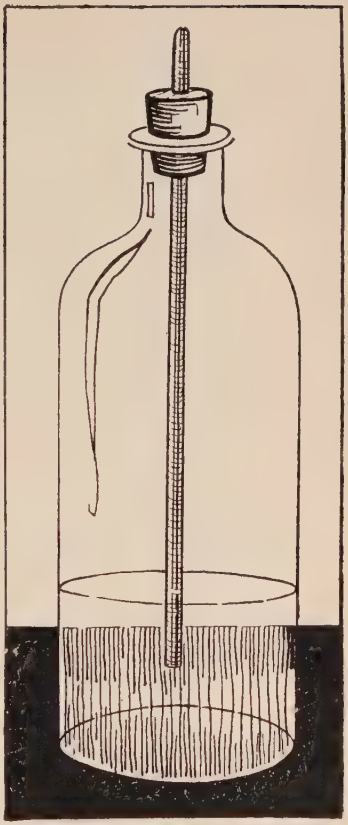


FIGURE 46. A compressed air fountain made by extending a glass tube through a cork into water in the bottom of a bottle.

The space in the top of the bottle was full of air before you began blowing. When you forced your breath inside, the air was compressed. When you took your

mouth off the tube, the way was opened for the air to return to its original condition, but in doing so it forced some of the water out of the bottle. The fountain will play as long as the air in the bottle is more compressed than the air outside. When the pressure inside and outside is equal, it will stop.

Whenever the air is taken away from one place, all the near-by air tries to rush in and fill up the space again. A place with no air in it is called a vacuum. In a vacuum cleaner, a little motor sucks the air out of the tube. Then the air in the room rushes in and fills up the space, and in doing so, takes the dirt and dust in the rugs along with it.

The Siphon

Another way to show the action of air pressure, or atmospheric pressure, as a scientist would say, is to arrange a siphon. You will need two glasses and a short piece of rubber hose. One glass is to be filled with water and placed at a rather high elevation. The other is to be empty, and to be placed near the first glass but at a lower level. A good way to arrange the glasses is to place them on a little shelf-stand, as in the illustration. What we want is to make atmospheric pressure do the work of taking the water out of the upper glass and putting it into the lower one.

Fill the tube with water and hold both ends closed with your fingers. Now put one end of the tube into the full glass, and the other end into the empty glass, and remove your fingers. All the water runs out of

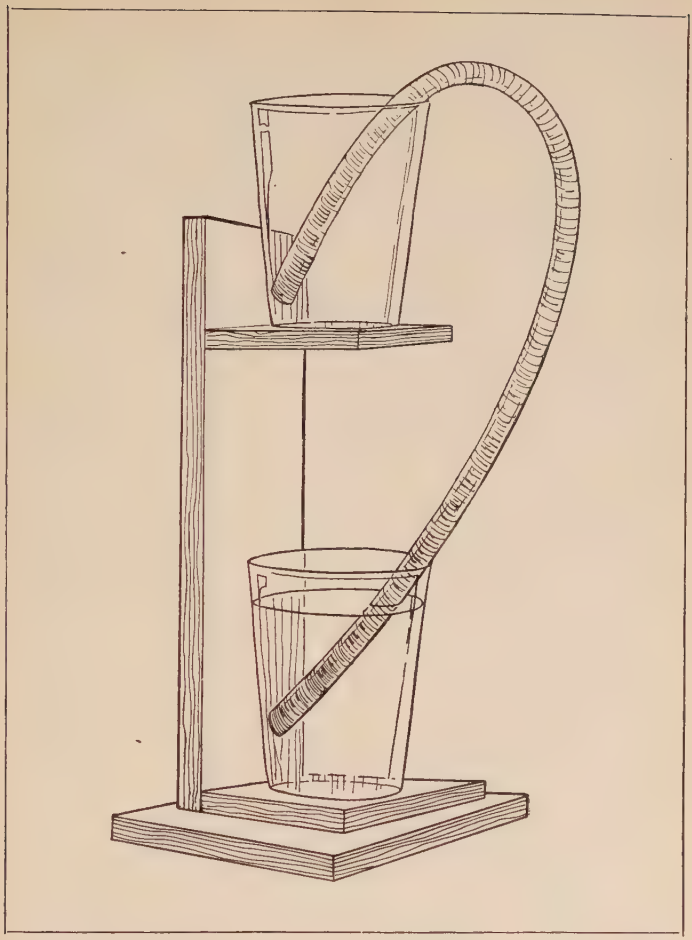


FIGURE 47. A siphon, made by the use of a short piece of rubber hose and two glasses placed at different levels, shows the action of air pressure.

the full glass into the empty one. When you take your finger off the lower end of the pipe, the water in the pipe starts to flow by the pull of gravity, but as it does so, it leaves a vacuum behind it, and the air pressing on the water level in the top glass tries to get in to fill the empty space. In doing so it forces the water in the glass into the tube. If the top glass could hold a hundred gallons, all the water would flow out through the tube just the same. (See Figure 47.)

If you have a fish tank, it will probably occur to you that this would be a simple way to empty the tank. You know how it disturbs and frightens the fish if you dip or pour out the water, but the siphon method does not disturb the fish at all.

When we drink soda water through a straw, we do not really suck up the water. We draw out the air in the straw, and the pressure of the air in the room trying to get in and fill the empty space we have made in the straw, forces the soda water up to our lips.

Man has taken advantage of air pressure to make it work for him. He has applied it to many kinds of machines, one of which is the pump. You can make a very correct model of a pump with an argand lamp chimney, two big corks, a dowel rod, and two pieces of rubber sheeting about one-inch square.

To Make a Model of a Pump

Fit one of the corks to the bottom of the chimney, being sure that it fits tightly. Then take it out and burn a hole through its center. If you use a large nail

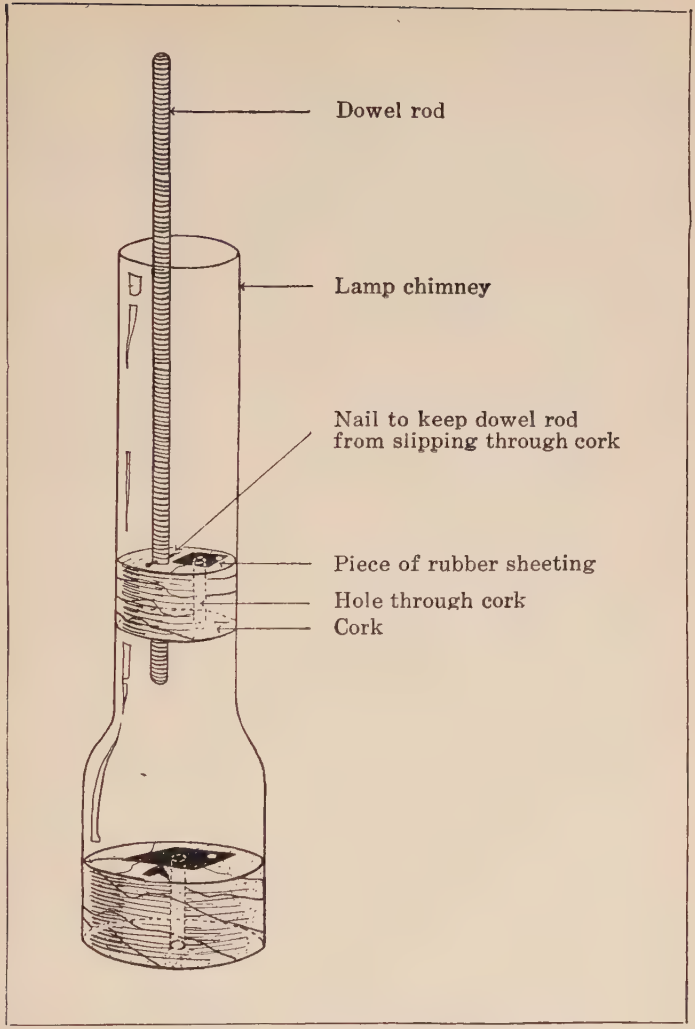


FIGURE 48. Model of a suction pump.

in burning the hole, its diameter will be an eighth of an inch, or more. Cover the hole with one of your half-inch squares of rubber sheeting. You can lay it on the cork so that the hole comes in the middle of the half-inch square. Fasten down one corner by a tack with a large head. Put the cork back into the bottom of the chimney, with the rubber inside, and force it tightly into place. The rubber over the hole forms a valve, which will open and close, as you will see later. (See Figure 48.)

Now take the second cork, which must be an easy fit for the top of the chimney, and burn a hole through its center, and another hole at one side. Through the middle hole must be thrust one foot of a small dowel rod, about a quarter of an inch in diameter. If the hole is not large enough for it, burn it out a little more. The rod should extend beyond the bottom of the cork enough so that you can drive a nail through the end. Drive another nail on the other side of the cork through the rod, so that the cork cannot slip on the rod.

Driving nails through a hardwood dowel rod is difficult. If you have a vise to hold the rod, and a drill to bore a small hole for the nail, you are lucky; but if you have not, use a small nail, or, better still, a brad. Care must be taken not to split the rod, especially near the end. Drive the nail slowly and carefully, and if a brad bends, pull it out and throw it away, and take a straight one. When the cork is made fast to the rod, treat the other hole as you did the hole

in the first cork. This will be your second valve, and the rubber must be on the top surface of the cork. The cork and rod, taken together, form the plunger of the pump.

Now try the plunger in the top of the chimney. If it fits too loosely, wind about a dozen turns of thin cotton string around the edge of the cork, which will very slightly increase its size. If it is still too loose, wind more. The cork must be snug in the chimney, but it must not be too tight for you to be able to move it up and down inside. Put the plunger in place, with the rod sticking out at the top, and shove the plunger down in the chimney as far as it will go. Your model pump is ready to work.

Put the bottom of the chimney into a pail of water, and pull up on the plunger. Air pressure closes the top valve and keeps more air from getting inside the chimney. A vacuum is thus formed in the pump. The air, pressing on the surface of the water in the pail, tries to get to that vacuum, and in doing so, takes water with it, driving the water through the lower valve. You can see the valve open and the water flow in. Take care not to pull the plunger entirely out but stop about one inch from the top.

Now push the plunger down. The pressure of the descending stroke closes the bottom valve, so that the water in the chimney cannot get out that way; but there is nothing to hold down the top valve, so the water runs through it above the top cork. With another up-stroke of the plunger, this water is lifted to

the top of the chimney, where it will flow out as the water flows out of the spout of a real pump. Since in the model there is no spout, the water merely runs down the outside of the chimney.

The glass chimney is a good thing to use in making this model, because you can see through it, and can observe every step of the working of the pump. This type of pump is called a suction pump.

List of Words

ozone
barometer
vacuum
siphon
U tube
caisson
atmosphere
X-rays

THE EARTH'S CRUST

SCIENTISTS have various ways of accounting for the existence of the earth. The best-known way is called the Planetesimal Hypothesis. According to this, another star came near what is now our sun and raised a tide upon its molten surface. But so great was the force, that instead of a slight rise as is the case when the moon acts on the ocean, great masses of material were drawn off and, the other stars having gone on, rotated about the sun as planetesimals all the way from microscopic particles to fair-sized chunks. These attracted each other and gradually fell together to make the planets, the separate masses being welded together by heat and pressure.

As the earth's mass cooled, it shrank and the surface wrinkled up into mountain ranges. These ranges were cut down by rain, glaciers and the like, and new wrinkles were formed by the still cooling earth. These processes have been going on for millions of years and are still incomplete.

In times when the wearing-down forces got ahead, the oceans were great shallow seas and the land mostly marsh with no mountains. In such times the climate was warm and wet, and tropical forests grew over all the earth. It was in such a period that the forests grew that later formed our beds of coal.

In times when the wrinkling got ahead, the oceans were deep and narrow and the land high. The climate then became cold and dry. Great forests of pines and other cold-resistant trees grew while glaciers came down from the poles to cover the northern and southern ends of the earth.

The Sea

Three-fourths of the surface of our globe is covered with water. One can sail from the west coast of South America, bound for Tahiti, and be one whole month sailing to get there. The time of sailing from New York to Liverpool on the fast steamers is from five to seven days. The sea varies in depth from about an inch to six miles.

The Atlantic Ocean averages two miles in depth, the Pacific, three. The highest mountains in the world are about as high above sea level as the deepest places in the sea are below it. The bottom of the sea is studied by scooping up some of it in a dredge. Sea dredges are usually hung on piano wire. Can you think of any reason why the wire is better than rope? If not, look up this point. The answer will be good material to put in your notebook.

In Figure 49 are shown some pieces of the sea bottom brought up by a dredge. The smooth, rounded pieces were, as you might guess, dredged up near shore, for they show by their shape that they have been rolled over by waves or the current of a river until they were made smooth. The other pieces were

taken from the deep sea, where no waves can ever reach, or the current of a river have any influence. As you see, the corners on them are sharp and show no wearing by the water.

If you ever go to Florida, and travel over what the engineers call "the railroad that goes to sea," you will

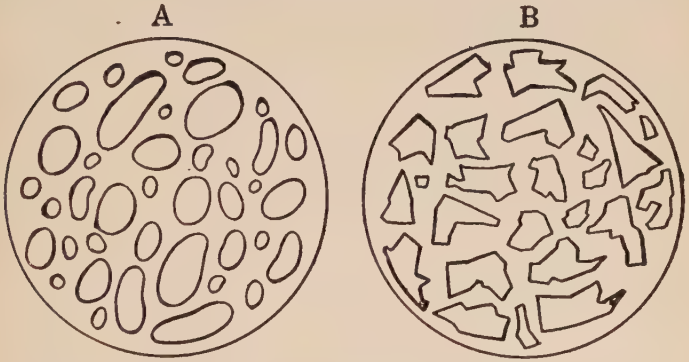


FIGURE 49. A—Pieces dredged from the bottom of the sea near the shore. B—Pieces dredged from the deep sea.

have a fine chance to collect some of the material from the bottom of the sea. As this road was being built, the engineers filled in the hollow places in the roadbed with material that came from under the sea. They did not want to dig away any of the soil from the little islands between which the railroad runs; so they took it from beneath the water through long lines of pipes by hitching a big suction pump to the pipes. When the train stops for any length of time, you can get out and scrape up a little of this material. In it you will find shells, corals, fossils, and many other

interesting things. The bottom of the sea is made up, like the land, of a layer of covering over bed rock. The covering is made up of the shells of animals, the bones and teeth of fishes, meteors, and whatever has washed down from the land.

Sunlight does not go very deep into the sea. Far down in the water it is dark except for the dim light given out by certain fishes and other animals. Their bodies phosphoresce and give off a pale glow like a firefly. The creatures at these great depths must withstand tremendous pressure. Can you suggest a reason why they do not collapse?

The waves along the seacoast wash away the banks Where the shore is made of soft rock, like the chalk cliffs in England, the work goes on quite rapidly. There is a church on the very edge of the cliffs to-day, which, when built, was one mile from the sea. The waves have washed away all this mile of land.

Sea water, like fresh water, can freeze, but only at a lower temperature. When it does so, however, it has to give up its salt. Therefore the ice made of sea water is not salty. This is fortunate for the seals and polar bears that live in arctic regions. They find places where the sun has melted little pools of water in the ice, and there they drink. Or they can lick the ice, and the warmth of their tongues will melt the ice enough so that they can satisfy their thirst.

The frozen sea water forms fields of ice of great extent, but only a few feet thick. It is called pack ice; the fields are called floes. Arctic explorers find great

difficulty in travelling over ice floes, because they are broken and piled up in rough hills by the movement of the water underneath. They are also full of treacherous holes and gaping spaces of water. It is fortunate for explorers that this ice is fresh, for they must drink, and they are often several days in crossing a large field of pack ice. By melting a little of the ice, they can get water to drink.

Rivers

Rivers have had a great deal to do with forming the earth's crust. Because of the pull of gravity they always seek a lower level, and continue to go down until they have reached the sea. They never run in a straight course, because the slightest obstacle turns them aside. They seek the easiest way down, and that causes them to keep turning, now this way, and now that.

Rivers carry a great deal of soil. If it were not for the soil that the River Nile carries, the people in Egypt would starve, for their country is a desert. The Mississippi River carries enough soil each year to make a hill two hundred and sixty-eight feet high, and one mile square. All rivers tend to lower their beds. They average about one foot in five thousand years. The Niagara River has done much interesting work upon its bed. It has cut back its bed seven miles. There is a tremendous volume of water in this river, and its current is swift. Also, the rocks of the bed are comparatively soft. On account of the fall, it has cut

both down and back. Geologists think that the amount of back-cutting here is about three feet a year. Do a little problem in arithmetic, and you will find out that the river has been over twelve thousand years in cutting to its present position.

A stream sorts over its stones. It can carry the big ones only when it runs swiftly. If water moves six inches per second, it will carry sand. Fill a basin full of water, and throw in a handful of sand. Now pour out the water, and however quickly you do it, you will find some sand left in the basin. Pour more water in and swash it around to try to collect all the sand. It will surprise you how hard it is to get all the sand out of the basin, and how much energy it requires to do it. Put into a glass of water a mixture of gravel, sand, and clay. Stir the mixture with a spoon and watch to see which of the three will settle first when you stop stirring. Where would you expect to find that a river had laid down its stones? At the point where it leaves the steep slope and runs out into level country, would you not? Rivers deposit clay where they run into the sea, and sometimes, also, where they overflow their banks. Such clay fields along a river's course are called flood plains. Mud laid down on a flood plain is called silt. In time, such mud hardens into rock and is called sedimentary rock. This rock is always found in strata; that is, layers. Rock in layers is said to be stratified. All stratified rocks have been formed from material sorted out by water. Nine-tenths of all the land is underlaid with stratified rocks.

Another kind of sedimentary rock is formed by the settling of animals' shells on the bottom of the sea. This kind is limestone. The Mississippi River has made a great deal of land in the southern part of Louisiana, by carrying down material and depositing it at its mouth. This land is called the delta of the Mississippi. Delta is a word that we get from the Greeks. It is their name for the letter *D*, and its shape, as they write it, is triangular, somewhat like a fan. The land that rivers build around their mouths nearly always has this fan shape; hence the name delta. In the Canadian Rockies there is a stream flowing into Lake Louise which is so full of glacial silt that it looks milky. The stream that flows out of Lake Louise is quite clear. This is an interesting example of water's depositing the material that it carries.

Rivers are like people in three ways: they are young, old, and middle-aged. We can tell whether or not a river is old, by the shape of its valley. (By young and old, you must remember that we are not speaking of years but of periods of time as reckoned by geologists.) When young, a river has a narrow, steep-sided, V-shaped valley; but when it is old, its valley is wide and saucer-shaped.

Sometimes rivers steal. The diagram (Figure 50) of the Red and the White Rivers shows how one stream sometimes steals from another. Branch *A* of the White River cuts back its bed until it reaches branch *D* of the Red River. It then takes the water that used to flow through *D*. In the same way, *B* can

rob *C*. The little mountain chain between the two rivers is a high ridge of land and is called a watershed.

Rivers are always cutting down mountains. Since there have always been rivers, you may wonder why there are any mountains left. They are left because

FIGURE 50. This diagram shows how the White River is "stealing" from the Red River. Branch A of the White River has cut back its bed until the water from Branch D, of the Red River, flows into it.

the process of cutting is very, very slow, and because the mountains have been slowly rising, too. The Laurentian Range of mountains that lies along the St. Lawrence River has been very much cut down by that river. Dripping water after a long period of time will do a great deal of work. Even if the drops carry no sediment, they will bore a hole in the surface where they fall. If they carry a sediment of lime, they form

stalactites and stalagmites, which are icicles of stone pointing at each other like the two carbon sticks in an arc light. Look up these words in a dictionary and you will probably find a picture to help you understand them. You can easily see how stone is formed when you look at the deposit of lime that comes, after a while, in teakettles. Sometimes a stalactite meets a stalagmite, and then a pillar is formed. In the Mammoth Cave in Kentucky there are some wonderful pillars of this kind.

Glaciers

A glacier is a river of ice. It is formed as follows: Snow falls very heavily on the tops of mountains, especially in winter, and does not entirely melt off in summer. Since it cannot stay on the mountain because the slopes are too steep, it slides down into the valley. When layer after layer has slid down and piled up in the valley bottom, the great weight of the snow packs it together until it becomes ice. Did you ever press together a snowball and pack it down hard until it became ice? The valleys in the tops of mountains are not level, and sometimes they are very steep, indeed; so the pitch of the land and the weight of the ice start the whole mass moving down. This moving mass of ice is a glacier.

We can measure how fast a glacier slides, or flows, by driving a row of stakes across it in a straight line. The two end stakes must be driven in the bank. If we leave the stakes for some time and then go back to

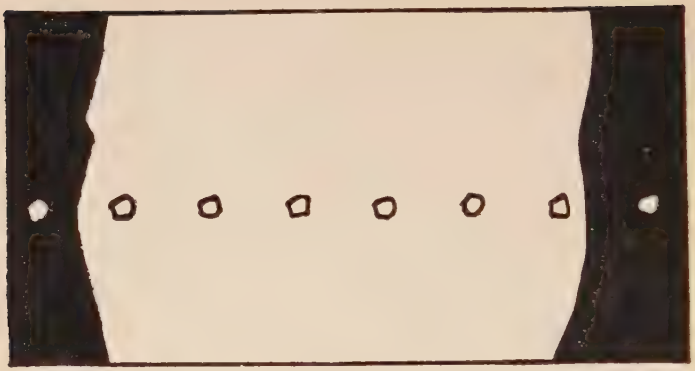


FIGURE 51.

FIGURE 52. These diagrams show how a glacier's movement can be detected by driving a row of stakes.

inspect them, we shall find that they have moved from the position in Figure 51 to the position in Figure 52. By keeping track of the time, we can measure the space of movement and tell how far the glacier moves in a day, or a month, or a year. The stakes will also

show that the glacier moved faster in the middle than at the sides. You can easily see that this must be so, as the ice would drag at the banks and slow down its movement along the edges.

A glacier picks up stones as it goes along and these act like a scraper. Surfaces which a glacier has passed are scraped, gouged, grooved, and scratched. Whenever you go into a country where glaciers have been, it is fun to be on the lookout for these marks, and lo-

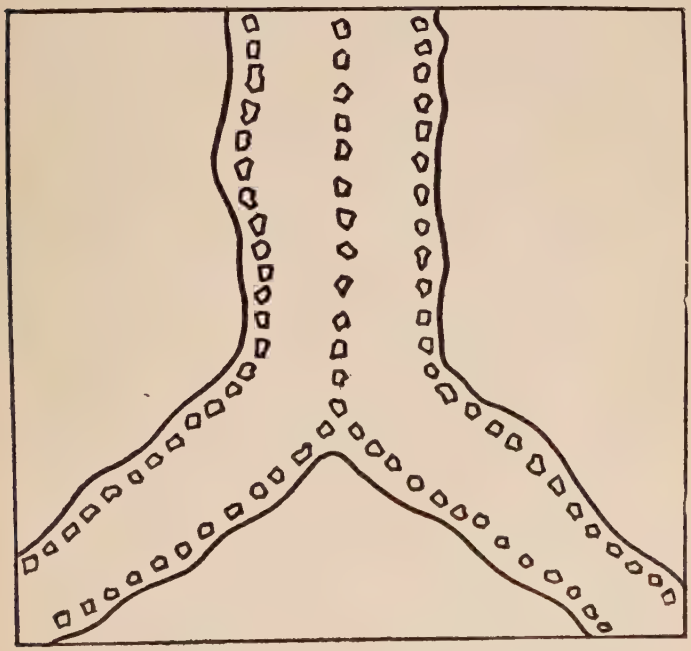


FIGURE 53. Two lateral moraines coming together form a medial moraine.

cate them. When a glacier melts, it drops its stones and leaves them lying about in heaps called moraines. Those dropped at the end of a glacier are called *terminal* moraines. Those dropped along the banks are called *lateral* moraines. Those dropped in the middle are called *medial* moraines. Figure 53 shows how two lateral moraines coming together formed a medial moraine. The most wonderful region of glaciers in America is Glacier National Park. I wish that every child in this country could make a trip to this wonderland; but every child can at least read about it. The United States Government publishes interesting pamphlets on it, in which there are many fine pictures. These are sold for very small prices. Many libraries have them on their shelves. Get one of these pamphlets, and learn about "cirques" and about how the glaciers "pluck" them out of the mountain side.

Icebergs

Where do icebergs come from? Many children think that they come from the sea, but this is not so. They come from glaciers that flow far enough to reach the seashore. The huge masses of ice come to the edge of the water and break off there with a noise like thunder. Then the currents in the water drift them away. When an iceberg floats, only one-seventh of its bulk shows above the water. If I measure the part of an iceberg above water and find that it is five feet, how thick do I know that it must be? Sometimes people who are dredging up the sea bottom, bring up large,

smooth stones out of the deep sea. As these are far out at sea, we know that rivers did not bring them: and since they are smooth, we know that water must have polished them. You will remember that the stones from the deep sea have sharp corners. There is only one way the stones could have got there—icebergs brought them.

Volcanoes

The materials thrown out by volcanoes are:—lava, steam, hot water, mud, gas, ashes, pumice, sulphur, and stones. Suppose you make a list in your notebook of the famous volcanoes. Begin with Vesuvius, and be sure to include Ætna, Krakatoa, Popocatapetl, Kilauea, Fujiyama, and our recently discovered Katmai. Mount Rainier was a volcano only yesterday, geologically speaking, and even to-day there is a place upon its top where great quantities of steam come out all the time, making large caves in the snow. Have you read the story of how Vesuvius once blew up and completely buried two towns that were built at its base? They were called Herculaneum and Pompeii. The hot ashes and other substances fell so quickly and in such large quantities that everything in those towns was preserved just as it was when the mountain burst. Scientists have dug up parts of both towns, and have found people in the streets, people in the houses, a baker just putting his bread into the oven, a lady in the act of putting on her jewels, and so on.

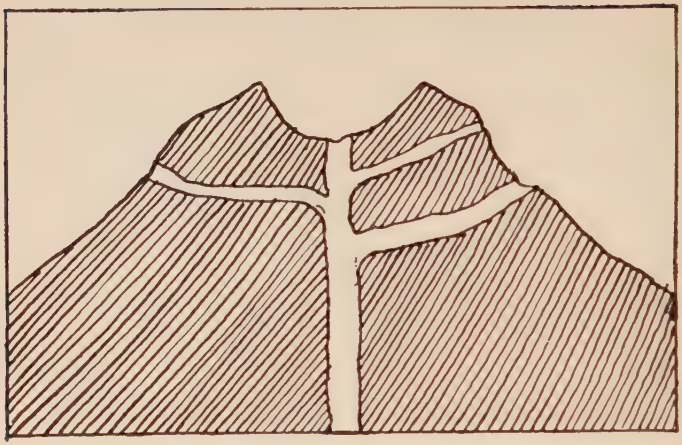


FIGURE 54. Cross section of a volcano showing formation of side vents.

The depression in the top of a mountain through which the hot material comes is called the crater. Sometimes the crater gets stopped up, either by rock which has fallen back into it, or by the hot material which has cooled and formed a sort of stopper, like a cork. When this has happened, other holes, called side vents, sometimes form in the sides of the mountain. Figure 54 shows how they form. Volcanic material, however, does not always come to the crust of the earth through the top of a mountain. Sometimes great cracks occur in the ground, through which ooze vast quantities of lava. In the states of Idaho and Washington there are beds of lava two hundred thousand square miles in extent and four thousand feet thick.

The force of the eruption of a volcano is sometimes very great. One volcano in Mexico threw out a stone half as big as a small house, hurling it a distance of nine miles.

Earthquakes

You remember we said that the earth's surface is wrinkling all the time. The surface is brittle and does not bend, but breaks. When a piece breaks we have an earthquake. If the surface is very weak so that it breaks and drops a little frequently, we have numerous small earthquakes. In Japan, for example, about three shocks occur daily, although most of them are too slight to be felt. In certain regions of the earth, called earthquake zones, the rock is stronger. Here it holds up until, when it breaks, there is a severe earthquake that may do considerable damage.

Scientists have invented delicate instruments, called seismographs, which record even the slightest earthquake. If we find it hard to believe that earthquakes are always going on, we have only to consult a seismograph and we shall find that it is true. But seismographs are not plentiful and it would be difficult to find one to use. However, you can make some earthquake detectors that will show you at least some of the unsuspected quakes. Cut a long piece of wood about an inch and a half square, into five-inch lengths. Shape each length into a little pyramid, leaving the point flat and just big enough so that the pyramids will stand on their heads. Put them away, all standing on their

heads, in some place where they will not get knocked over, and look at them frequently. Sometime you will find all of them fallen down, with the points extending in the same direction. This will show you that there has been a slight earthquake shock. Set them up so that if one should fall accidentally it will not knock over the others. (See Figure 55.)

Once there was a terrible earthquake in Portugal. In order to get out of the way of the falling buildings,

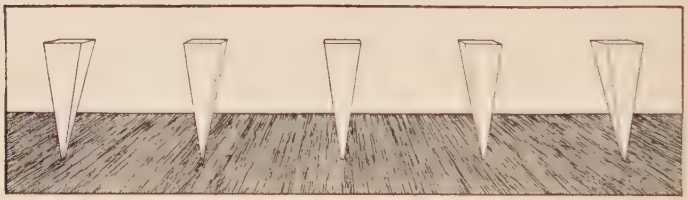


FIGURE 55. Wooden pyramids used as earthquake detectors.

people ran down to the sea and swarmed out upon a great wharf. But the disturbance under the crust of the earth that was causing the earthquake suddenly caused the sea to lift its level, and the water covered the wharf and drowned hundreds of people. The city of San Francisco was once nearly destroyed by an earthquake and by the fire that followed.

Besides the sudden breaks that cause earthquakes, there are slow changes that are raising or lowering whole regions of the earth. Scientists tell us that the entire Great Lakes region in North America is slowly tipping. So also the coastline of New York and New Jersey is slowly sinking, while that of Norway is slow-

ly rising. Whenever we see steep mountains near the edge of the ocean as in Norway we know that the land is slowly rising; but if there is a long stretch of flat country leading to a sea bottom that slopes so gradually as to leave rather shallow water extending miles from shore, we know that the land is sinking.

We get our living from the crust of the earth. Certain substances, such as salt and soda, we get directly from the crust itself. Some foods we get indirectly. That is, we eat plants and animals, and animals either eat each other or eat plants. But plants eat the earth's crust; thus it is the source of our life.

The crust is not very thick. The deepest canyons and wells are only about one mile down. Scientists can prove that the lava thrown out by volcanoes does not come from very far beneath the earth's surface. No one knows what is in the center of the earth, but it is supposed to be extremely hot.

When we ask how old the earth is, how it got its shape, and how long man has been on it, we can get the answers only by studying the crust; that is, the rocks. We can get the best measurement through a study of certain rocks that contain radium and similar substances. We know how long these substances can exist, and how much of them should be formed. From these data we can compute the age of the rocks. From them we estimate the age of the earth to be about fifteen hundred million years.

Imagine a river in the very, very long ago, flowing into the sea. On the sea bottom was already a layer

of sea animals' shells pressed together by its great weight, until they had become limestone. This river ran faster in the spring, and so it brought down quantities of gravel, which it spread out in a layer on the sea bottom above the limestone. Then in the summer it ran more slowly, and could bring down nothing but sand. This it spread out, also, in a layer on top of the gravel. By that time there were three layers: limestone, gravel, and sand, or sandstone as it had become. The three layers were buried deeper and deeper and baked by the heat from the inside of the earth. The crust of the earth was wrinkled and folded by the terrible force beneath, and the sea bottom with the three layers was lifted up until it became the top of a mountain.

We are able to prove that the top of the mountain was once under the sea, because we can find in the rocks fossils of animals that we know could have lived nowhere but in the sea. A fossil is the petrified body of a plant or animal. Fossils of tree ferns and other tropical plants have been found in the arctic regions. What does that prove about the climate? When Columbus discovered America there were no camels or elephants here. They once lived here, however, for we find their fossil remains in our rocks.

As soon as a mountain is lifted up, it begins to be torn down by rivers, frost, wind, rain, and earthquakes. One can tell by its shape whether a mountain is old or young. When old, it has become smoothed and rounded and lowered. New mountains are rough

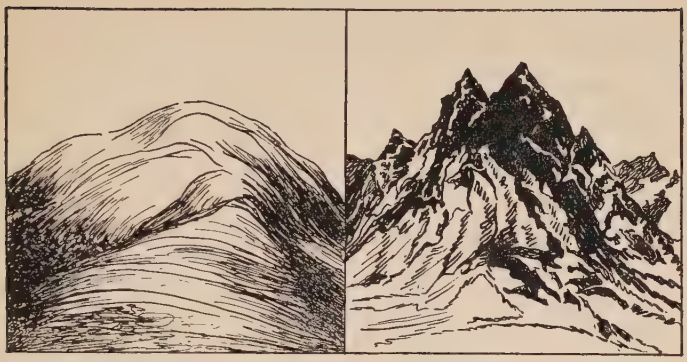


FIGURE 56. Older mountains are rounded and lower than the newer mountains, which are rough and jagged, with high peaks.

and jagged, with great high peaks. The oldest mountains in our part of the world are the Laurentian Mountains in Canada. They are estimated to be fifty million years old. The youngest mountains are the Coast Range on the Pacific Ocean. These are only about two million years old. (See Figure 56.)

Some of the most important rocks of which the crust of the earth is formed are: lava, sandstone, limestone, granite, marble, slate, and coal. We have seen how the first three are made. Marble is made from the subjection of limestone to great pressure. The pressure changes the formation of the original limestone, and it becomes marble. By great heat and pressure, some of the precious stones have been formed in the same way out of common materials. In the section of this book about chemistry you were told how the diamond is formed.

Slate is made of thin layers of clay pressed together until hard. In some places we can see where the layers have been bent and crumpled by pressure. Sometimes the folds were too thick, or too stiff to bend; so they cracked instead. Often one of the sides of the crack would slip past the other and form what geologists call a "fault." Whenever we find a long, gentle slope ending in a sharp cliff, we may suspect a fault. There are many such faults in the Canadian Rockies. A large fault occurred near San Francisco at the time of the earthquake.

In the very long ago, there were strange animals on the earth not found anywhere to-day. We say that they have become extinct; that is, they have died out altogether. We find their bones buried in the layers of rock. Differences in the earth's crust have always made differences in plants, animals, and men. That is why geography has a great deal to do with the making of history.

List of Words

earthquake
sediment
sedimentary rock
a stratum
two strata
stratified
Pompeii
petrified
water shed
stalactite
wrinkle
deposit
flood-plain
pumice
lava
pyramid
limestone
fossil
crater
eruption
stalagmite
glacier
moraine
floe
volcano
arctic
meandering
seismograph
gravel
granite

CEMENT AND CONCRETE

CEMENT is clay and limestone thoroughly mixed together and burned. There are many kinds, but Portland cement is the kind chiefly used for building purposes. Concrete is made of a mixture of cement, sand, and water. It is one of our most important and valuable building materials, since it is cheap, strong, easily handled, and fireproof. Also, it is very long-lived and resists the weather. When reinforced, that is, strengthened by iron rods, it is capable of bearing enormous strains. It can easily be dressed to a smooth surface, and takes a variety of colors.

In making concrete, the proportion of cement to sand may vary widely. There may be equal parts, or from two to six or more parts of sand to one of cement. In your experiments it would be best to use equal parts. This mixture makes a very strong concrete.

An outfit for making toy bricks, consisting of molds, tools, materials, and a book of directions and plans can be bought for a small sum. If you can get one of these outfits it will be the best way for you to learn to use cement. If not, you must make your own molds and devise your own tools. You will need a smoother,—for this an old case knife may be used. You must also have a tamper. This is a tool with which to mash and press down the concrete in the mold. The bottom

should have a smooth surface with square corners. This part should be attached to some sort of upright rod. The tamper can be made of wood, but is not very heavy if so made. A metal tamper is better.

Cement is sold at lumber yards, by contractors who do plastering, interior decorating, etc., and, in big cities, by companies who handle nothing but cement. In country districts, the general store nearly always has it. It comes in barrels and in one-hundred-pound sacks. The best way to get some is to ask the contractor to sell you a few pounds from one of his broken sacks. As for the sand, go out and dig for it! Beach sand is best. It will be better to sift the sand to get out all stones and gravel. When you have your materials together you are ready to begin work.

Into a bowl holding a quart or two, measure equal parts of cement and sand. Mix this material thoroughly, turning it over and over for a long time. Then for every six parts of the dry mixture take one part of water. You will think that you have made a mistake about the water—that it surely ought to be ever so much more than that; but if you use more you will have trouble. Continue the mixing process, working the water thoroughly into the dry material. When it is of even texture and smooth, put it into your mold, a little at a time, tamping it down frequently. Here is a good recipe:—

6 spoons of cement
6 spoons of sand
2 spoons of water

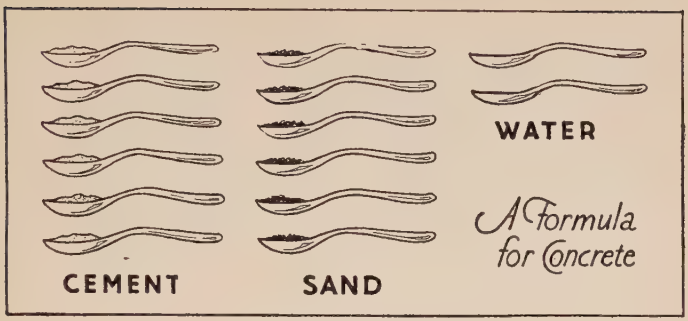


FIGURE 57.

This quantity will fill several small molds. If you have a little brother or sister, a set of these bricks will make them a pleasing gift.

When the mold is smooth, you can take away the sides, leaving the form standing up by itself. Even now you can pick it up if you are careful; but if you want to make sure not to injure it, you had better let it stand for a few hours without touching it. If you make the bricks in the evening, you can let them dry over night. In the morning they will be "set," but not, as yet, very hard. Now you must "cure" the bricks. It is done by placing them in water and letting them soak long enough to take up all the water they will absorb. This should be done once a day for a week; and by the end of that time the bricks will be very hard and durable.

SOILS

THE crust of the earth was once all solid rock. Now its outside layer is broken up into soil. But a little way down under the soil, we come to the hard, solid rock again. This is called bedrock. In New York City bedrock is at the surface, and when a man wants to build his house, he must blast the bedrock before he can dig the cellar.

In Chicago the situation with regard to bedrock is very curious. Chicago was originally built on a swamp. When buildings of any size were first built in that city, they began gradually to sink into the soft soil. It was necessary to drain the land before a stable foundation could be had; and when really big buildings were erected, the engineers found that they must dig down to bedrock and plant great concrete pillars on it for the buildings to rest on. Under the Marshall Field Building these shafts had to be ninety feet long. In other parts of Chicago, it is not so far down to bedrock.

When we ask how the top layer of the earth's crust got broken up into soil, we find that there were six forces which did it. They are running water, wind, frost, waves, ice, and plants. Water performs an astonishing amount of work and is a great sculptor. Here is a partial list of places in the United States

where running water has carved up the country. Sometime go to a library and take this list with you to look up the regions: "Balanced" rocks in Colorado; The Dells of Wisconsin; Ausable Chasm; The Flume, in the White Mountains; Grand Canyon of the Colorado River, in Arizona; Starved Rock in Illinois, especially Horseshoe Canyon; Deer Park, near Starved Rock.

The wind changes the face of the land by moving the loose soil, as in a country where there are sand dunes. The wind can actually move a big hill of sand for miles—not all at once, of course, but little by little. However, the wind does the most of its sculpturing by using sand as a tool. If you have ever been caught in a sand storm you know how the flying grains will cut the skin until blood flows. The windows in lighthouses, and in dwellings near which there is sand, are sometimes so cut by the grains that they become "ground" glass; that is translucent, instead of transparent as they were originally.

For the work of frost, look up the Devil's Lake region in Wisconsin. There is no end to the queer tricks that Jack Frost does in this part of the country. As for waves, we have already seen what they did to the coast in England. The work of ice is best shown in that done by the great ice cap. This was a sheet of ice that came down over the northern part of this continent. It was one mile or more thick, and extended entirely across the United States. When it melted, it dropped its stones just as glaciers do. It

thus left a map of itself drawn in stones, and scientists can tell just how far it came. Look at the map of it in Figure 58, and you can tell if your own locality was ever covered by it. This mass of ice did a vast amount of work in making North America what it now is. It turned old rivers out of their beds, and made them run in new ones. It scrubbed off the tops of the hills, and filled up the valleys with heaps of stones. In fact, it brought millions of stones down from the north and left them lying about on the surface in deep layers. One of the things it did was to scoop out the holes now occupied by the five Great Lakes. So you see that it was busy away back in the old days, one hundred thousand years or so ago. It acted like a great millstone, and ground up the surface of the earth into soil.

The part that plants have had in making the soil is a very quiet one compared with the spectacular doings of the ice cap. They have just added the substance of their dead bodies to the top layer. This substance has mingled with the mineral material, and added the vegetable element to soil. If you will fill a fine sieve with earth and sift it, you will get some fine, soft black material which is vegetable matter, and is made up of pieces of dead plants. The sand and little stones left in the sieve are part of the bedrock. There is another way in which plants affect the surface, and that is by the action of their roots, especially the roots of large trees. It is well known that such roots are strong enough to split big rocks by growing into cracks in them.

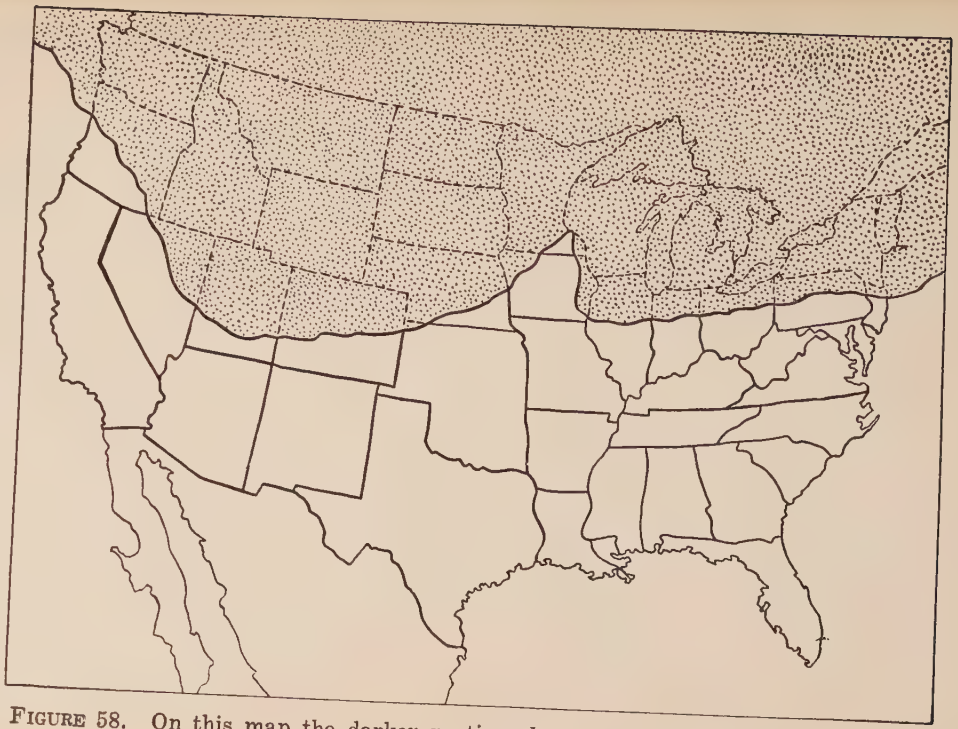


FIGURE 58. On this map the darker portion shows the part of the United States covered by the great ice cap.

Soils differ very much in the length of time that they can hold water. You can arrange a test for finding out the water-holding power of several kinds of soil. You will need a half cupful each of clay, sand, and dirt, three little gas globes like that on top of the glass in Figure 59, three glasses, and three squares of cloth four by four inches. Pieces of an old sheet will do for the last named. Set a globe on the middle of each cloth square, and put clay in one, sand in another, and dirt in the last. The material should be pressed down so it will be in a compact mass. Now set the globes in the tops of the glasses, holding the cloth so that the contents will not spill out as you move the globes.

If you want to make this a race, like the dissolving test, get two people to help you. To make it a fair race, you should get the quantities of earth as nearly equal as possible. Put a cup in front of each glass, and in each cup put exactly the same amount of water. This is to be poured into the globes at the same time. Watch the bottoms of the globes for the first drops to appear. Time the water, and see how long it takes to get through. Sand wins the race. The dirt is second. The clay has not shown a single drop in its glass; and you may as well know that the water would never get through it.

If you were to make a garden after having tried this experiment, you would know just what to do about the soil you had to use. If it had too much clay in it, you would know that it would hold the water and be too wet, so that the roots of your plants would rot. If it

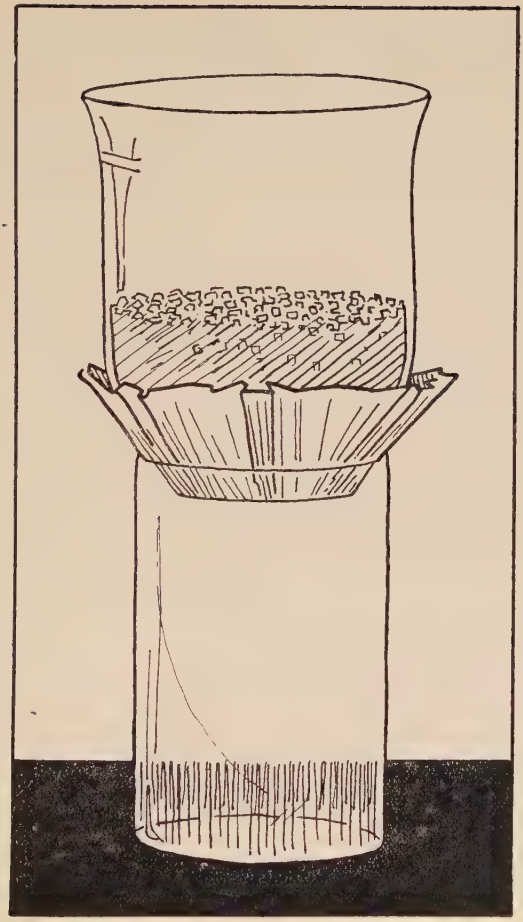


FIGURE 59. This shows correct arrangement of material to test water-holding power of soil.

had too much sand in it, you would know that the water would run through, and your plants would be likely to become dry and wither.

There is a fine way to prepare the soil for a garden, but it is rather expensive. First dig down deeper than you expect the roots of your plants to reach, and spread out a thick layer of clay. Then put on top of that the kind of soil your plants like best. When it rains, the roots will drink as much as they need and let the rest run down through the dirt. The layer of clay will hold this extra moisture, and when the top soil gets dry and hot from continued dry days, the roots can suck up the moisture from below. Here again we meet with capillary attraction. As the hot paraffin climbed up the wick of the candle, so the extra moisture climbs up through the soil.

THE WEATHER

YOU know that the sun seems to be red at sunset and sunrise. Why does it never look red in the middle of the day? That is because at sunset and sunrise we see the sun through more of our atmosphere than at noon. If you look at Figure 60 you can see just how it is. The line *BC*, showing position of the sun with reference to the earth at sunrise or sunset, is longer than the line *AB*, which shows the position of the sun at noon.

But why does the atmosphere make the sun appear to be a different color? It s because of the billions and billions of tiny particles floating in the air. These absorb light in such a way as to make the sun, or any other light at a distance, appear ruddy. These particles are dust from the wide-spreading plains, smoke from cities, and the pollen of plants; some of it is pumice from volcanoes. Scientists believe that the dust and ashes from a big volcanic eruption can go entirely around the earth.

When men go up in balloons they say that the sun appears to be blue. That is because they see it through so much less atmosphere. The air would become filled with dirt and different kinds of particles if it were not for the rain and the wind. They are a sort of natural laundry for the air. When a man wishes to test the

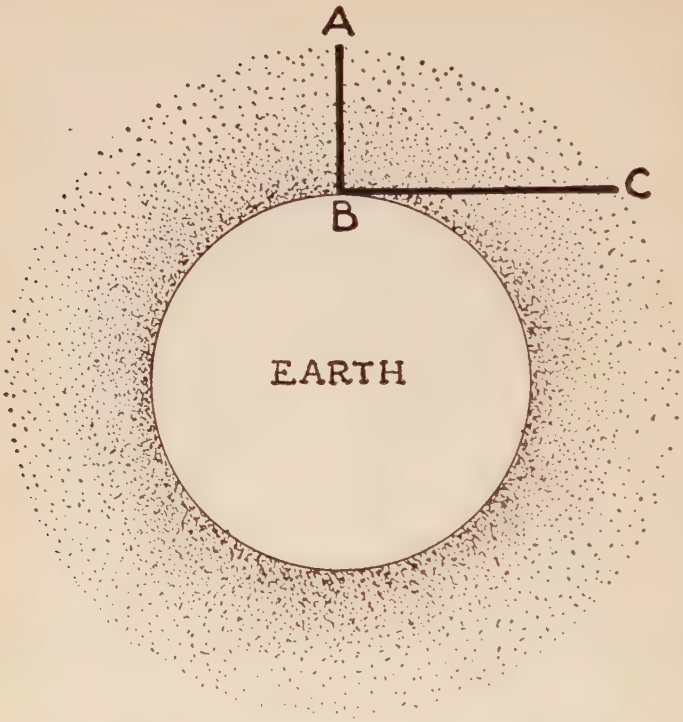


FIGURE 60. This diagram shows why the sun looks red at sunset. We see it through much more atmosphere at sunset than at midday. (The line B C is longer than the line A B.)

air of any place for purity, he covers little sheets of glass with wet shellac and puts them out in the air for a while. Then he collects them, puts them under the microscope, and counts the pieces of dirt on them.

The higher up we go from the earth, the colder it is. If you have ever seen an aviator getting ready to make

a flight, you must have noticed what very warm clothing he put on—a coat with a high collar, both lined with a thick layer of wool, big gauntlets on his hands, and sometimes even fur-lined boots. The tops of high mountains are covered with snow that never melts, even on the hottest summer days. But you will say that since we go nearer the sun as we ascend, you should think it would get warmer instead of colder. You were told in your study of heat that it is not the direct rays of the sun that warm the atmosphere but the absorbed and re-radiated rays. Considering the immense distance of the sun from the earth, the tiny bit of distance that man is able to go up from the surface is nothing. The line around a high mountain above which the snow never melts is called the snow line. In the Rocky Mountains, this line is at thirteen thousand feet. But in Alaska, the snow line is only a few feet from the sea level. Can you figure out why this is so?

Sometimes when boys play baseball they get hit with the ball. Everyone knows that the ball hurts much more if it hits squarely than it does if it comes at an angle and gives a glancing blow. The same thing is true of the rays of the sun. They are not so hot in the parts of the earth where they fall at an angle; but at the equator, where they fall straight down, they are very hot. They heat the air quickly, and as soon as it gets warmer, it begins to rise. But as it goes higher it comes into colder surroundings, as we have seen, and so begins to cool off. As soon as it cools it becomes

heavier, and has to sink down again. Thus it goes around and around in a sort of circle. Figure 61 shows you its movement. Does this remind you of the movement of the smoke under the glass when you experimented with the candle?

The earth is warmed during the day and cools off at night. The water heats more slowly than the land,

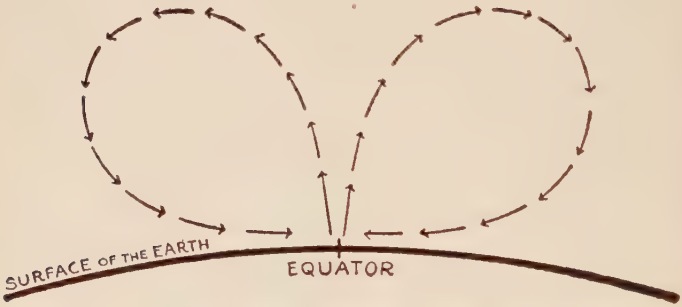


FIGURE 61. Arrows show direction taken in movement of the air.

and also cools more slowly. When the sun comes up and begins to warm the earth, the air soon gets hotter over the land than over the water. When air warms, it rises; so the air above the land begins to rise. Then the cooler air, lying above the water, has to flow toward the land to take the place of the warm risen air. This movement is the explanation of the fact that a cool breeze nearly always blows from the sea toward the land in daytime. Indeed, it is this heating and cooling, with its resulting rising and falling, that makes the weather.

Clouds

When water evaporates, it turns from a liquid into a gas called water vapor. It is then invisible. Fog is often wrongly spoken of as water vapor. Fog is composed of extremely small drops of water. They are so little and so light that the air holds them up and they seem not to fall, only because they fall so very slowly. The white cloud that one breathes out in cold weather is a form of fog. So, also, is the mist that forms on the outside of a glass of cold water in warm weather. Many children believe that this water comes *through* the glass, but this is not so. It comes out of the air surrounding the glass, and condenses on the glass, because that surface is cold.

A quart of warm air can hold more moisture than a quart of cold air. When warm, moisture-laden air cools, some of the moisture in it is squeezed out. When we look up into the sky and see clouds we can be sure that the air where they are is cooler. If you watch a cloud for a while, you can sometimes see it disappear, or see a bulge grow out on its surface. The sun and the air lift up water from the earth which often appears in the sky as clouds. This water may have come from a great distance. In the particular cloud you are looking at, the water may have come from a thousand miles away. If it came from the sea, would the cloud have any salt in it? Why not?

Clouds are of three principal kinds:—cirrus, cumulus, and stratus. The best way to learn to recognize these different kinds of clouds is to get some good book

on the weather, which will be sure to have pictures of them. The stratus clouds are usually in layers like the stratified rocks. The word *cumulus* is a term from the Latin, meaning mound. So a cumulus cloud is a great round heavy-appearing mass that often looks like a mountain. Thunderheads are of this kind. The cirrus clouds are a white, filmy variety formed in the highest cloud region.

Here is a little table that shows the height at which these varieties of clouds usually lie.

Cirrus clouds—about 10 miles.

Cumulus clouds—about 1 mile.

Stratus clouds—very low.

Snow

In your study of crystals you were told that snow appears in crystals of a six-sided form. There is no limit to the wonderful, beautiful, and fairy-like forms in which these crystals occur. Go to a library and get some book that will show pictures of them. You might take along your notebook and copy a few of the prettiest ones. (See Figure 62.)

Anyone who ever made a snowball thinks of snow as being a very cold substance; and yet the snow that covers our land in winter acts as a warm blanket that protects the earth. It keeps any heat that may be in the earth from going away, and it prevents the bitter cold from piercing down into the soil. Did you ever stop to think that grains, such as wheat, would freeze during the winter if it were not for the protection of

the snow? After winter begins, if the snow is late in falling, or if it falls in scant quantity, the cold gets down into the ground more than usual, and we have a late spring in that year. At such times the plants suffer, and are often killed. If they are such as pro-

FIGURE 62. Some of the many beautiful forms which snow crystals reveal.

duce crops upon which people depend for a living, then the people suffer, too.

Sometimes snow turns into sleet. If you are in the habit of observing the weather (it is a fine habit to cultivate) you have found out that sleet comes when there is a high wind to drive the snow. When you have been out in sleet, you must have noticed how it cut your face. If you had a piece of sleet under a microscope, you could tell why it cuts. Warmer air somewhere has partially melted the snow crystals together into jagged pieces, which have sharp corners and edges.

Dew and Frost

Dew forms on the grass more easily than elsewhere because the grass blades, being very thin, and being nearly all surface, cool quickly. Then the water vapor in the air, coming in contact with these multitudes of

cool surfaces, condenses into drops. If cold enough to freeze, we have hoar frost. If the drops that gathered on the glass of cold water in warm weather had frozen, frost would have formed.

Wind

Winds blow because the air tries to escape from any place where it is pressed down; and because, when air moves away from a place, the surrounding air flows in. Scientists have invented an apparatus to measure the speed of the wind. It is called an anemometer. They speak of the speed of the wind as its velocity. The pressure of the wind against large surfaces can be calculated. It increases as the velocity of the wind increases. Here is a table that shows these facts.

TABLE OF WIND VELOCITY

Description	Speed per hour	Pressure in pounds per square foot
Gentle breeze	7 miles	23-100 of a pound
Fresh breeze	11 miles	64-100 of a pound
High wind	27 miles	3-½ pounds
Gale	36 miles	6-½pounds
Hurricane	76 miles	29 pounds
Violent hurricane	95 miles	45 pounds

You can easily make a weather vane that will always show the direction of the wind. On a piece of paper draw an oblong one inch by eight inches. In this space draw the shape of an arrow with a broad

tail. Cut out the oblong with scissors, and fold it down the middle the long way, with the arrow on the outside. Now cut out the arrow with the paper folded, and both sides will be exactly alike. Trace this pattern on a piece of thin wood, and cut it out with a scroll saw. When the wood is smoothed and sandpapered, balance it on a knife blade to find its balance point.

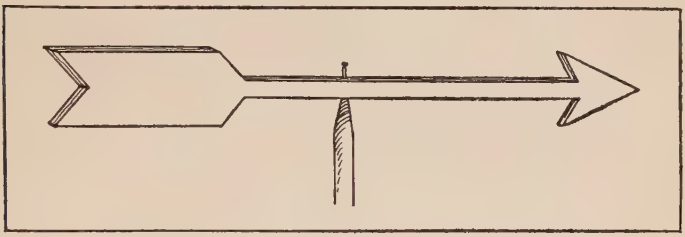


FIGURE 63. A weather vane, mounted

Mark this spot with a pencil. Put the arrow into a vise and pound a large nail through at the mark, then pull out the nail. The vane part of the weather vane is finished; but you will want some sort of mounting for it. Any kind of stick will do, the length depending upon where you want to place your weather vane. Whittle the stick thin at the top so that there will be very little friction as the vane swings around; but before you do so, drive in, then pull out, the nail that will hold the vane in place. If you try to drive it in after you have thinned the wood, the stick will split. When you are through tapering your mounting, put the nail through the hole in the vane and into the hole in the stick and give it one smart tap. (See Figure 63.)

The second nail should be a size or two smaller than the first nail, so that the vane can swing easily. Do not put oil on the weather vane. When you set it up, put it in a place where it will not be sheltered from the wind in any direction. Does the arrow point the way the wind blows, or the way the wind comes from? What keeps it pointing towards the wind?

Storms

Storms are a little like animals in that they have favorite hunting grounds and regular trails that they follow. If you look in some of the books on the weather, you will find maps showing the favorite trails of storms and some of their haunts. Medicine Hat, a county in Alberta Province, Canada, is the source of many of our North American storms. When a thunderstorm is approaching you can tell in a general way how far off it is. You have already learned that sound travels one mile in five seconds, and that, because of the tremendous swiftness of light, you see the flash of lightning as soon as the spark jumps. If, then, you will listen for the thunder, and count the seconds that pass between the flash and the thunder, you can tell how far away the storm is.

Perhaps you do not know how fast seconds occur. You can easily learn by a very simple piece of apparatus. Tie some object weighing an ounce or two to a piece of string. Lay the string under a book on the edge of the table, letting the weight dangle over the edge. Now draw the string out from under the book

until it is thirty-nine inches long. If you swing the weight back and forth it will mark seconds, provided the string is just thirty-nine inches long. When you have practiced with this apparatus a while, you will be able to count seconds without any help and you can measure the distance of an approaching thunderstorm.

The United States Weather Bureau

Our Government has a whole department devoted to the study of the weather. This department is called the Weather Bureau. It employs thousands of men whose business it is to watch the weather, keep records of what it is doing, make weather maps, and send out warnings of storms. The Weather Bureau sends out a weather report to every newspaper in the country every day in the year.

What good does it do for the Government to spend so much studying the weather? Cover up the rest of this page with your hand and try to think of some answers before you read any farther. Then read on and see if you got some of them right.

Saves crops by warning farmers of storms, wind, and frost.

By warning of approaching storms, prevents ships from sailing into them.

Warns airplanes of storm areas and high winds.

Saves lives and property by foretelling rise and fall of rivers in time of flood.

These are only a few of many, many ways that the

Weather Bureau helps the people. The study of the weather makes it possible to save many millions of dollars every year.

The Weather Bureau has a series of flags that announce the coming weather; and every child should be able to read and understand a few of the more common ones.

You will enjoy having a set of weather flags. The best way is to make them of cloth; but good ones can be made of paper with very little trouble. Of course, you must not put the paper flags out of doors. Make the flags as shown in Figure 64, and tack them with small tacks to dowel rods three-eighths of an inch in diameter and about one foot long. The Government displays its flags on masts. To display yours, you can use a long stick mounted on some sort of solid base so that it will not tip over easily. Beginning near the top of the stick, and running down the side, bore holes (just a little larger than your dowel rod) into which you can place your flags. Here are a few exercises in weather forecasting which you can use to practice on while you are committing the flags to memory.

Weather Forecasting

Fair and warmer—black triangular pennant above; white square below.

Fair and colder—-reverse.

Fair, with cold wave—white square above; white square with black square center below.

Storm, with cold wave—black square flag with red

Clear or fair.

Rain or snow.

Local rain or snow.

Cold wave (45 or lower).

Temperature signal. Shown above a weather flag indicates warmer. Shown below a weather flag indicates colder.

Storm.

Easterly winds.

Westerly winds.

The easterly pennant shown above a weather flag indicates northerly (and easterly) winds; shown below a weather flag indicates southerly (and easterly) winds.
The westerly pennant shown above a weather flag indicates northerly (and westerly) winds; shown below a weather flag indicates southerly (and westerly) winds.

Two storm flags indicate a hurricane

Figure 64. Flags used by the United States Weather Bureau to signal the weather forecast.

square center above; white square with black center below.

Storm and warmer—black triangle above; red square with black center below.

Storm and colder—reverse.

Rain or snow and colder—blue square above; black triangle below.

Rain or snow and warmer—reverse.

Local rain or snow and colder—blue-and-white square above; black triangle below.

Local rain or snow and warmer—reverse.

Rain or snow with southeast winds—blue square above; red pennant below.

Rain or snow with northeast winds—reverse.

Rain or snow with southwest winds—blue square above; white pennant below.

Rain or snow with northwest winds—reverse.

Fair with southwest winds—white square above; red pennant below.

Fair with southeast winds—square white above; white pennant below, and so on, with many other combinations.

List of Words

cirrus	anemometer	equator
cumulus	velocity	vertical
stratus	sleet	Weather Bureau
triangular	weathervane	pennant

ASTRONOMY

IT is about eight thousand miles *through* the middle of the earth, and about twenty-five thousand miles *around* the middle of it. A wheel turns around on a center part called an axle. The earth turns around on an imaginary line called its axis. The axis of the earth is not perpendicular to the plane of its orbit but is tilted $23\frac{5}{10}$ degrees to one side.

Suppose you make a little model of the earth. To do this, you will need an old ball, a long knitting needle, and a piece of thick wood about five by eight inches. Push the needle through the center of the ball. The needle represents the axis. Now bore a hole near the middle of one end of the stand, into which you can slip the needle with the ball on it. That hole is not to be bored straight in, but must be tipped on a slant of twenty-nine degrees. If you know some one who has a set of drawing instruments, ask him to lend you the thirty-degree triangle and mark the thirty-degree slant on a piece of paper with a heavy black line. Set the paper up by the board, and slant the bit a little less than the black line. If you have a protractor you can get the angle exactly. Draw the line in the same way, and hold the bit parallel to the line when boring. In case you make the slant too much or too little, bore another hole near the first one. You can bore a number of holes without spoiling the base; so you have a

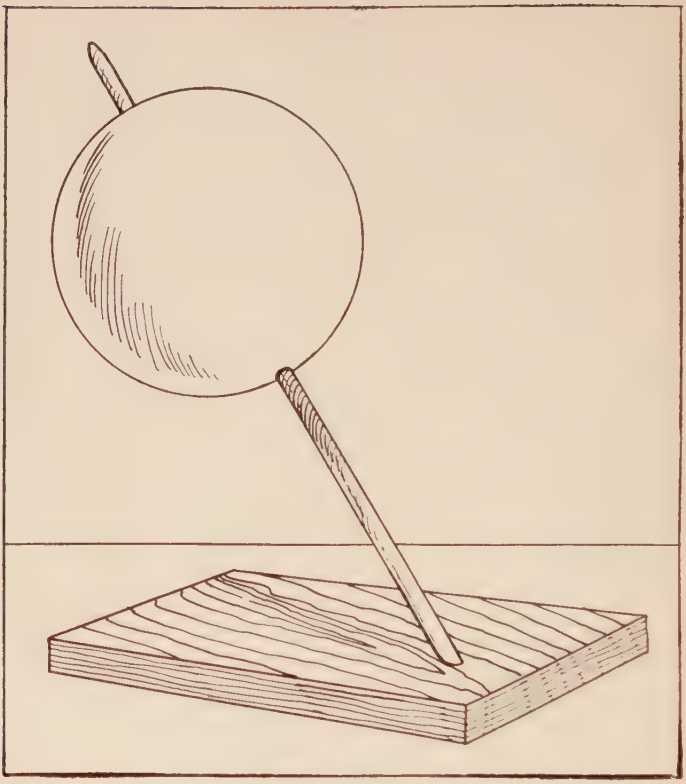


FIGURE 65. Model of the earth on its axis made by inserting a knitting needle tipped at an angle of 23½° through a ball.

number of chances. When you have the proper slant, draw a pencil line around the right hole and slip in your needle with the ball. Make a pencil mark on the surface of the ball at about the point where you live, and stick in a pin there. The head of the pin will represent your city. (See Figure 65.)

Light a candle and set it beside your model of the earth so that the flame is opposite the center of the ball. Now turn the ball around slowly on its axis (the needle). When the candle light shines on the pin it is daytime in your city; but when the pin has passed around into the shadow of the ball it is night. In like manner, the sun, shining on the earth turning on its axis, just as you turned the ball on the needle, lights only part of the earth at a time, thus causing day and night.

Some night put out all the lights and make another experiment with your model. Place a lighted candle on the table and taking the model in your hand, walk around the table, all the while slowly twirling the ball. You will see that when you are at one side of the table there will be a time when one pole of the ball, owing to the slant of the axis, is never out of the light, while the opposite pole is never in the light. When you walk to the other side of the table, the conditions are reversed. The pole that could not get out of the light is now in the dark, and the dark one is light. In the same way, at a certain time of the year, one part of the earth receives more sunlight than another part. When we get less sunlight, owing to the tilt of the earth's axis, it is winter in our part of the world. You can also see that when we are having winter, it is summer on the other half of the world—that is, when the northern half has winter, the southern half has summer, and the reverse.

The earth is not a star; it is a planet. A star is a body shining with its own light, while a planet is a

body shining with light reflected from some sun. Our sun is a star, and shines with its own light. Astronomers think that the stars which we see in the sky at night are suns like our sun. With the eye alone one cannot tell the difference between stars and planets; but astronomers, with their powerful telescopes, see the planets as globes, while the stars continue to look the same, whether observed through a telescope, or with the eye alone. Our moon is also a small planet. As the sunlight is reflected from a piece of bright tin, so the sunlight is reflected from the surface of the moon, and all other planets.

Stars, that is, suns, are self-luminous. We have one substance on our earth that is self-luminous—phosphorus, which comes from bones. The head of any match, other than a safety match, contains some phosphorus. If you will take the match into a dark closet and gently rub its head with your fingers, the skin of your finger tips will glow with a soft, dim light. You must not do this often, however, because much phosphorus on the human skin will cause a bad sore.

Our earth is not the only planet that swings around the sun; there are seven others. Set your lighted candle in the middle of the table, to represent the sun, and lay out around it eight marbles to stand for the other planets and the earth. If you can imagine these marbles rolling around the candle in circles, you will have an idea of how the planets swing around the sun. However, there will be this difference—the marbles will be nearly all one size, while the planets are of dif-

ferent sizes. We may say that the sun's family consists of eight children. Among these children, the earth is number three. Here are the names of the others: Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune.

The group of the sun with all his children and grandchildren is called the *solar system.* If we could get up above it and look down, we should see the sun

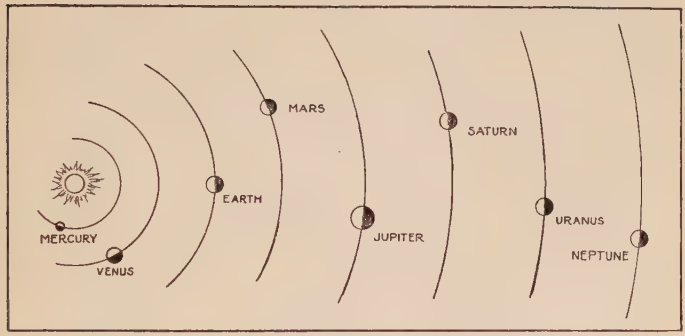


FIGURE 66. The planets in the order of their distance from the sun. The curved lines represent sections of the orbits made by the planets in their revolution around the sun.

in the middle, many, many times larger than any of his family, shining with great brilliance. Next to him, we should see a tiny planet called Mercury, the baby of the family. Next beyond Mercury we should see Venus. We can see her from the earth in late summer and autumn, looking like a big, bright star in the west. But Venus is not a star; she is a planet. Looking still farther out from the sun, we should see our earth; then Mars, which is a small planet; then Jupiter,

which is the very largest of all the planets; then Saturn; then Uranus; and last, and farthest from the sun, Neptune. (See Figure 66.)

But if the planets are different sizes, what sizes are they in proportion to the sun and to our earth? Figures will show this, but they will not mean very much to you because they are so huge. A little model of each, showing the relative sizes, will give you a better idea. Cut a board about a foot square for a base and fasten to it the things here suggested to represent the planets. We will let Mercury be the head of an ordinary pin. Stick a pin into the board and write its planet name beside it. Let a larger pin represent Mars. If you can find a pin three times as big as the first one let that represent Venus. If you cannot find one, use a bead of the right size. For our earth you can use the head of an ordinary hatpin. Uranus may be a marble the size of a nickel. For Neptune, a golf ball will do nicely. Saturn must be a ball as big as a silver dollar.

Fasten the spherical objects in place on your board by gouging out a small bit of the wood, filling the hollow with a drop of glue, and setting the object in place on the wet glue. Such glue will not stick very tight, but it will harden and hold enough to keep the objects from rolling off the board. On the scale of this model, we could not represent Jupiter at all, because it would be larger than the whole model. A boy and girl who made one of these models, set it beside their fish globe, which was fourteen inches in diameter, and the bowl stood for Jupiter on this scale.

The earth moves around the sun in a path that is very nearly a circle. This path is called an orbit. Each planet has a different orbit. The orbit of the earth is finished in one year, or three hundred and sixty-five days. Mercury's orbit is smaller than the earth's, so Mercury's year must be shorter than ours. It is only eighty-eight days long. How would you like to live on Mercury and have your birthday come around every eighty-eight days? Here is a table showing the length of time required for the different planets to complete their orbits:

ORBITS OF THE PLANETS

Mercury— 88 days	Jupiter—12 years
Venus—225 days	Saturn—29 years
Earth—365 days	Uranus—84 years
Mars—687 days	Neptune—165 years

Between Mars and Jupiter is a cloud of tiny planets called asteroids. You remember that we said the planets were supposed to have been formed by the falling together of planetesimals. It is thought the asteroids are planetesimals which have not yet fallen together. The asteroids, too, swing around the sun, and each one has its own orbit. The rings around the planet Saturn are formed of millions of little stones like asteroids, except that they are smaller.

Just as the sun has a number of bodies swinging around it, so do some of the planets have smaller bodies swinging around them. Such bodies are called satellites. The moon is the earth's satellite. Mars has two tiny moons, one of which is only seven or

eight miles through the middle. Here is a table showing the number of moons belonging to the different planets:

TABLE OF MOONS

Mercury—0	Jupiter—5
Venus—0	Saturn—8
Earth—1	Uranus—4
Mars—2	Neptune—1

There has been a great deal of discussion about canals on the planet Mars. Naturally, this planet interests us most, for it is near us in space and favorably situated for observations from the earth. One astronomer, Professor Lowell, has devoted most of his time to the study of Mars, and the discussion about canals is largely based on his observations. The subject seems to fascinate people everywhere, and newspaper men and magazine writers have printed many articles filled with ingenious guesses and imaginings. But this is all that we really *know* about canals on Mars:—At regular intervals, Mars shows a white cap at its two poles. The caps come down over the sides of the planet for quite a distance, and then retreat again toward the poles. When the caps withdraw, certain lines become more distinct than they were before. These lines appear to be as straight as if drawn with some mechanical instrument. When the caps increase again, the lines fade out somewhat, although they never entirely disappear.

People have guessed that the caps are snow fields like those near our own north and south poles, which

must appear to the Martians, if there are any, to come down on our earth in much the same way. The brightening of the lines is supposed to be the springing up of wide strips of vegetation along canal banks at the time of the melting of the Martian polar snows. This melting snow would fill the canals with water, and cause trees and other plants to spring up. In like manner, as the poles put on their caps with the coming of winter, the vegetation would fade, as it does on earth with the coming of the cold. It certainly seems reasonable to suppose these things; but one must remember that these are only speculations. Professor Lowell has written a book about it which is easy for people who are not scientists to read, and you had better get it from the library and read it. It contains many maps, and photographs of Mars and its canals which you will find interesting.

What we know about the planets and the stars is largely due to the telescope. Find out who invented the telescope, and read the very interesting story of his adventurous life. But even the nearest heavenly bodies are so very far away that the best and biggest telescopes help only a little. We cannot see the surface of any planets except Mars and our moon, which are the nearest to us of any of the heavenly bodies. We can see the light they reflect from the sun, and the dense, thick layer of clouds around them; but that is all. To be sure, we can see the rings of Saturn, but they are not part of its surface, and lie outside its atmosphere.

In the month of August, the earth, in swinging through its orbit, passes through a swarm of little bodies somewhat like asteroids. These we sometimes see as "shooting stars." They are always there; but we do not see them until their friction with our atmosphere heats them. (You will remember how friction causes heat.) When they meet our atmosphere, they begin to glow and become incandescent.

The moon is near enough to us so that we can see the mountains on its surface. These mountains are all extinct volcanoes and, compared with earth mountains, they are very high, very large, and very sharp in outline. This sharpness of outline shows that the moon mountains have never been worn down by rain or snow, or any form of water; and they prove that the moon has no atmosphere. We could not live if we went there; for there would be nothing for us to breathe. Here is a little nonsense rhyme that helps us to remember about the moon's lack of atmosphere.

Little Timmy Toon
Sailed up to the moon
In a silver spoon.
When he got up there,
Oh! *how he did stare*—
There wasn't any air!

The stars lie in large groups called constellations. The groups have names, such as Vega, Pegasus, The Silver Chair, Orion, and The Dipper. The last is the easiest to find, for, unlike the others, which have no

likeness to their names, it really looks like its name. It is composed of seven large stars; and if you were to draw an imaginary line from one to the other, you would have the picture of a long-handled dipper, with the handle bent down near its outer end. The two stars that make the front of the dipper are called the

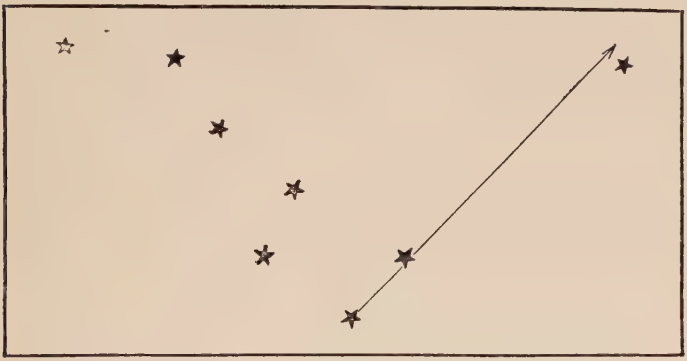


FIGURE 67. Diagram showing how to locate the North Star by means of the stars in the Dipper.

Pointers, because by them we can locate the North Star. If you draw an imaginary line from the lower of these two, up the sky to the upper, and continue the line until you come to the next bright star, you have located the North Star. The line will not point exactly at the North Star, but a little beside it. Figure 67 shows just how much.

Comets are groups of little stones like Saturn's rings. Some comets are not relatives of the sun family, and come from somewhere outside the Solar System. Their behavior is strange and little understood.

Another mystery of the sky is the Milky Way. It is thought that it may be made up of very fine particles that might be called star dust.

Sometimes the sun has large black spots upon its surface. Some astronomers think that these spots are places where the sun is beginning to cool. Others think the spots are huge storm centers on the sun. Telescopes show us that they are holes in the surface of the sun, for as the sun turns around, we see the holes in profile, and the sun looks like an apple with a piece bitten out. The spots change their shape, size, and location. When they appear, our electrical instruments on the earth are disturbed; so astronomers think that the spots have something to do with electricity. When there are spots on the sun, you can sometimes see them through smoked glass. If you will take a rather large piece of glass (part of a broken windowpane is all right) and hold it in a candle flame until it is coated with carbon, you will have a good screen through which to look at the sun.

The clock, as well as the telescope, is an instrument used in astronomy; for it measures the time of the turning of the earth upon its axis. The first clocks were run by the swinging of a pendulum. The little weight on the string with which you learned to measure seconds, is a sort of pendulum. Set the book on the string, and imagine that your pendulum is controlling a clock. If the clock went too slowly, what would you do to the pendulum, and why? Most clocks nowadays are controlled by an escapement. If some

jeweller will give you an old broken clock, you can see how it works.

Before there were clocks, men used sundials. The objection to these was that they could not show the time on a stormy day, or at night, since sunshine was necessary. Obelisks were used in the same way as sundials, their shadows marking out the hours. Our pioneer ancestors used to carve a groove in the cabin floor which they called the noon mark. When they saw the shadow coming close to it, they knew it was time to get dinner. Since we know just how many inches of candle will burn in a given time, we can measure the passing of time by making marks down the length of a candle; and people used this method before they had clocks. Another way of marking the passing of time was to burn a tarred string which had knots tied in it every few inches. Then came the hourglass, a device for measuring time by running sand through the narrow neck of a glass vessel. (See Figure 68.)

Thousands of years ago the Chinese had what they called a water clock made by placing a series of tanks, one below the other. A certain definite quantity of water ran from one into another. The Mandaneo savages make a water clock with a coconut shell. You can do this, also. Take half a coconut shell, and bore the smallest possible hole in the middle of the bottom. Set the shell in a pail of water. The water will run in through the hole, and you can time it to see how many minutes it takes the shell to fill and sink. If you cannot find a coconut shell use an empty

FIGURE 68. Different means of marking the passing of time before clocks were invented. These are: sun dial, knotted tar string, hour glass, water clock, and marked candle.

FIGURE 69. A shadow stick to measure change of the sun's direction.

tin can, and punch a hole through the bottom with a nail. Because of its shape, however, the can will not sit in the water so well as will the shell.

As winter approaches, the sun sets farther and farther toward the south. It is fun to make a shadow stick, and measure the change of the sun's direction from time to time. The shadow stick is a board 14 x 2 inches, with another board nailed vertically to one end of it. The second board should be as wide as the first and three inches high. Point the long board toward the north, and on any given day at noon mark the position of the shadow of the little board on the long board. It is a good plan to write down the date on the line of the shadow. Then at noon, one week from the date, mark the next position of the shadow. As winter goes away the shadow will return. (See Figure 69.)

LIST OF WORDS

astronomy	constellation	planet
astronomer	Saturn	comet
Mercury	Uranus	axis
Jupiter	Neptune	solar system
Venus	orbit	incandescent
Mars	satellite	asteroid

GRAVITY

CRUMPLE the page of a newspaper into a tight ball. Hold it in your hand a few feet above a table, and let it fall. What made the ball drop to the table? Of course you know that the answer to this question is gravity. But is gravity still pulling the ball down, now that it rests on the table? You can answer that question by imagining what would happen if you should jerk the table out from under the ball. It would then fall to the floor. And if you removed the floor the ball would go on down to the ground. Unless something stopped it, it would continue to fall until it reached the center of the earth. Gravity is a force of great importance. We are so used to seeing it at work that we forget how important it is. If it should cease to work for one second of time, the earth would fly away from the sun, the water on it would spill off into space, and we should all perish in the winking of an eye.

Gravity is like half a pair of scissors—it does not work alone. The other half is a force called centrifugal force. We owe our position in the universe to the balance between these two forces. The attraction of the sun is what holds the earth in place, and likewise holds in place all the planets. If the sun's attraction should cease, all his family would fly off into space and be lost. On the other hand, if centrifugal force should

cease the earth and the planets would fall into the sun, and be burned up. You can easily illustrate these facts for yourself. Tie a heavy string securely around the instep of an old shoe. Make sure that it cannot slip off. Wind several turns of the string around your hand so that you will be sure not to let go of the string; or you can make a loop in the string and put your hand through it. Now swing the shoe around in the air in vertical circles. The shoe is the earth. Your hand is the sun. The string is gravity preventing the earth from leaving the sun. You can feel how hard the shoe pulls on your hand, especially when you swing it faster. That pull is centrifugal force.

If you will read the life of Galileo, you will learn that he made some very curious discoveries about falling bodies and gravity. He made his experiments in the Leaning Tower of Pisa. Why was that a good place to experiment with falling bodies? Can you make a rough sketch of the Tower to show this point? Galileo's discovery was that light objects and heavy ones fall to the earth from the same height in the same time. One would naturally suppose that heavy things would fall faster; but the experiments at Pisa showed that it is not so. A falling body goes 16 feet in the first second; 64 feet in the first *two* seconds, and 144 feet in the first *three* seconds. Thus you see that the speed of the falling increases very fast.

When we say that an object has weight, we mean that we can measure the pull of gravity on it. The weighing scales measure this pull. At the Bureau of

FIGURE 70. The Leaning Tower of Pisa.

Standards, in Washington, D. C., is kept the United States standard pound. It is a piece of metal which weighs exactly one pound. All other pound objects should weigh the same.

Anything heavier than water will sink in it; but anything lighter will float. Ice being lighter than water, floats in water. A piece of iron is much heavier than water, and would sink to the bottom, as you know. If you had a glass half full of water and dropped a screw into it, you know that the screw would sink. But if your glass were half full of mercury, you would be surprised to see that the screw would float around on top of it as a chip of wood would float on water. This is because the mercury is heavier than the iron of which the screw is made.

Gravity always pulls toward the center of the earth. No matter where you stand on the surface of the earth, *up* is always away from the center and *down* is toward it. If I hold a pendulum in my hand it will swing about until it settles down in a straight line from my fingers to the center of the earth. It feels the pull of gravity just as the magnet felt the pull of the magnetic north pole. Suppose you take the weight and string you had before, and fix it nicely as an adjustable pendulum. For the weight a large key may be used. The string ought to be rather thin and light. Across a thick board about three inches wide and six or more inches long, make a saw cut as shown in Figure 71, cutting a little deeper across the edges than across the middle. Through this cut draw the string, and it will

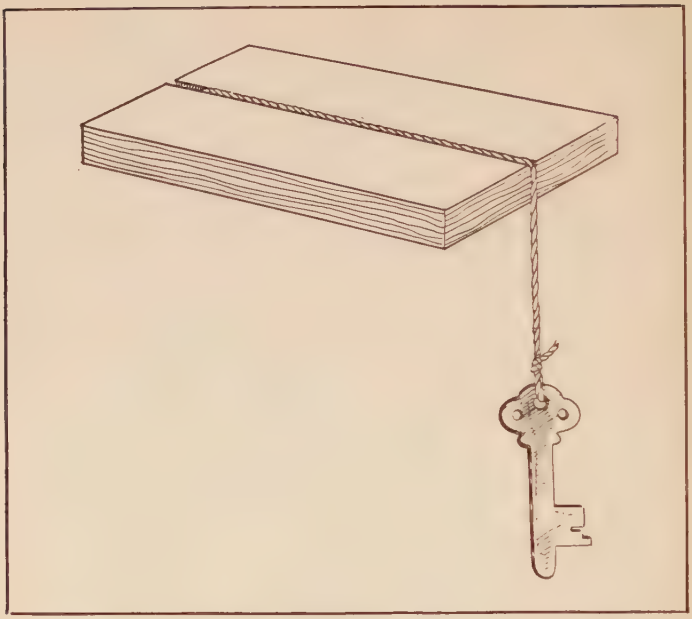


FIGURE 71. Block and pendulum used in experiment to prove laws of the pendulum.

be loose enough so that you can adjust its length, but still tight enough to hold the weight of the key without slipping. Set the block and pendulum parallel with the edge of the table so that the key can swing without hitting anything. Let the weight come to rest. We say it hangs down. But if there were a child on the opposite side of the earth with a pendulum, he would say that his pendulum was hanging down, though it would be pointing in the opposite direction from that in which ours points.

Now set your pendulum swinging. The time it takes to go from one side to the other and return is called its vibration. The pendulum vibrates from side to side as your vibration stick did, only, of course, much more slowly. The part of a circle which the pendulum describes in the air is its arc. Time your pendulum with a watch and see how long it takes to make any given number of vibrations. Now draw the key farther to one side in swinging it, so that it will describe a greater arc, and see if that makes any difference in the time of vibration.

Perhaps it would make a difference if the weight were heavier. Try adding to the weight. You can hook a buttonhook into the key. You see, by trying it, that the weight makes no difference. Now try to make a difference by drawing the string through the groove a little, thus lengthening it. This makes a difference in the time of the vibration. By these experiments you have demonstrated the laws of the pendulum:

The time of vibration is not dependent upon the length of the arc.

The time of vibration is but slightly dependent upon the weight of the pendulum.

The time of vibration *is* dependent on the length of the pendulum.

A pendulum thirty-nine inches long marks off seconds.

LIST OF WORDS

gravity	Galileo	Pisa
pendulum	centrifugal	float

SIMPLE MACHINES

THE musical scale of only twelve semitones is the very simple material out of which all the wonderfully complicated music of modern times is made. From the seven primary colors of the rainbow we get thousands of tints and shades. All arithmetic is based on the ten figures. In the same way, all the complicated machinery in the world is only different arrangements of a few simple mechanical devices. These are called simple machines. They are seven in number.

1. The lever.
2. The wheel-and-axle.
3. The toothed wheel.
4. The pulley.
5. The inclined plane.
6. The screw.
7. The wedge.

One might even say that the simple machines are only three in number; for all wheels are really levers, and screws and wedges are really inclined planes.

The Lever

Get a strong stick three feet long and an inch square, and taper it a little at one end. Then get a large stone and, pushing the stick under the stone, try to lift up one edge of it. You see that it is very hard to lift. Now get a piece of square wood three or more inches

thick and make it triangular by sawing off half of it the long way on a diagonal. Set this three-cornered block near your stone, put the stick on top of it with the thin end under the stone, and try to lift. You see that the stone comes up much more easily. You have applied the principle of leverage. Your stick is the lever. Your three-cornered block is the fulcrum, the stone is the weight, and the thrust of your arm is the power. These four things always appear when we use levers.

Now drive a large nail into a board, and pull it out with the claw hammer. Can you tell which is the lever, the fulcrum, the weight, and the power in this case? The lever is the handle of the hammer. The fulcrum is the bell (or nose-end) of the hammer. The weight is the tendency of the nail to stick in the board. The power is the pull of your arm. You found that the nail came out very hard. That was because the fulcrum was not in a good place. If you had taken a small flat block half an inch thick and set it under the bell of the hammer the nail would have come out much more easily. Try it. Now you have a better fulcrum. In pulling out any nail it is always well to get the fulcrum placed right (near the nail).

There are three kinds, or classes, of levers, the difference being in the position of the weight, lever, etc., with regard to each other. This is hard to explain in words, and is best shown by illustration. A study of Figure 72 should give you a good idea of the different classes of levers.

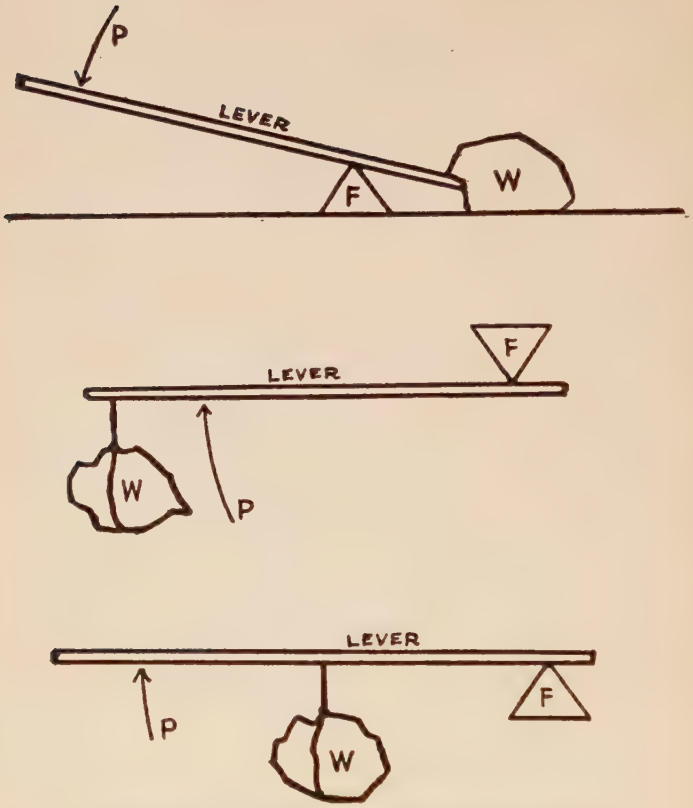


FIGURE 72. Three different kinds of levers.

A teeter-totter is a lever. If a man and a boy are to sit on a teeter-totter, where must the man sit, as compared with where the boy sits? The scales with which the grocer weighs is an application of the lever. Can you tell which is the lever, weight, etc., in this

case? The weight is whatever is put in the scoop. The lever is the beam of the scale, the fulcrum is the point of balance, and gravity is the power.

The Wheel-and-Axle

To any boy or girl who ever owned a cart, the wheel-and-axle needs no explaining. There are two kinds of axle—the common kind and the ball-bearing kind. The idea of the ball bearings is to reduce the friction in the axle by reducing the rubbing surfaces. If you whirl around an ordinary wheel, it soon comes to rest because of its friction; but if you spin around a good bicycle wheel, it will continue to turn for a long time.

Toothed Wheels

These are sometimes called gears, especially in an automobile. If your mother has a "Dover" egg beater,

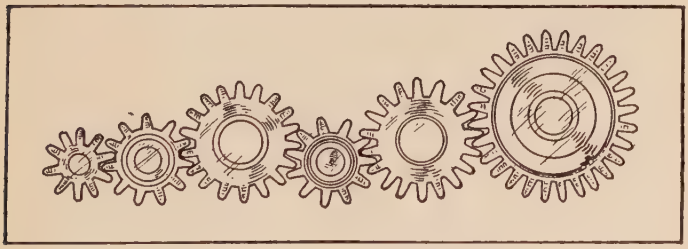


FIGURE 73. A "train" of gears.

you have an excellent example of gears. Look at it closely, and see how the teeth on the little wheel fit into, or engage, as the mechanic says, the hollows between the teeth in the big wheel. In one turning of the

big wheel the little wheel goes around many times. But it takes more power to drive the big wheel. If the handle were on the little wheel, it would take less power to turn it; but it would have to turn ever so many times to make the big wheel go around once. An ice-cream freezer is turned by gears, and works on the same principle. (See Figure 73.)

The Pulley

The pulley is a labor-saving machine. With the help of several pulleys we can raise a weight with far less muscular force. You can prove this for yourself if there is a shed in your yard where no one will mind if you turn some screws into the woodwork. You will need three or four little metal pulleys, which you can buy at the hardware store for a few cents, and a twenty-five cent spring balance. Fill a tin can with stones, and pour in sand until the whole weighs exactly two pounds. You can fasten a bail on the can by punching two small holes near the top, on opposite sides, and putting a piece of wire through the holes. Screw one pulley to the top of the doorframe; thread a heavy string through it, tie one end to the can, and make a loop in the other end. Through the loop should go the hook on your spring balance. Then lift the weight (the can of stones) from the ground to the top of the door. The scale of your balance will show you that the force needed to raise the weight is pound for pound; that is, if the weight is two pounds, the pull must be two pounds. Now screw in another pulley on

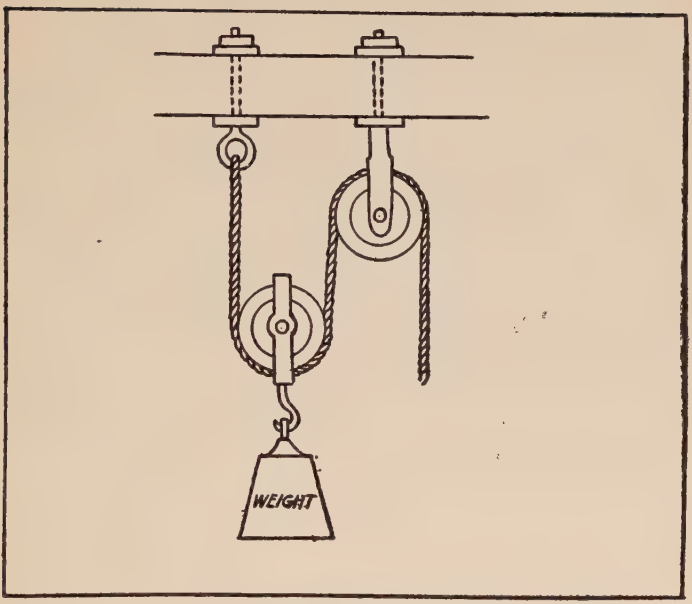


FIGURE 74. This shows arrangement of pulleys and rope for lifting a weight.

the bottom of the doorframe, and a third beside the first at the top. This time the string is to go from the can to the first pulley, through it and down to the second one at the bottom, through it and up to the third at the top, through it and down to your hand. Now hook on the balance and pull. You will see that it takes less pull to raise the same weight. This is the principle of pulleys. The greater the number of pulleys, the less pull it takes to raise the weight. Place the additional pulleys so as to make the strings as nearly parallel as possible. (See Figure 74.)

FIGURE 75. This man is using the inclined plane to get the barrel into his wagon.

The Inclined Plane

When a dealer has a barrel of goods too heavy to be lifted from the sidewalk to a wagon, he has an inclined plane over which he can roll the barrel. (See Figure 75.) A railroad going up into the mountains is also an example of an inclined plane.

The Screw

There are five parts to a wood screw. The head is the broad top part, and in it is the slot. Just underneath the head is a smooth part that looks like a large nail. This part is the shank. Below the shank the thread begins. This is the "curly" part of the screw. The thread goes down the length of the screw, and ends in a little sharp point, which is called the worm. (See Figure 77.) A wood screw is so made that as

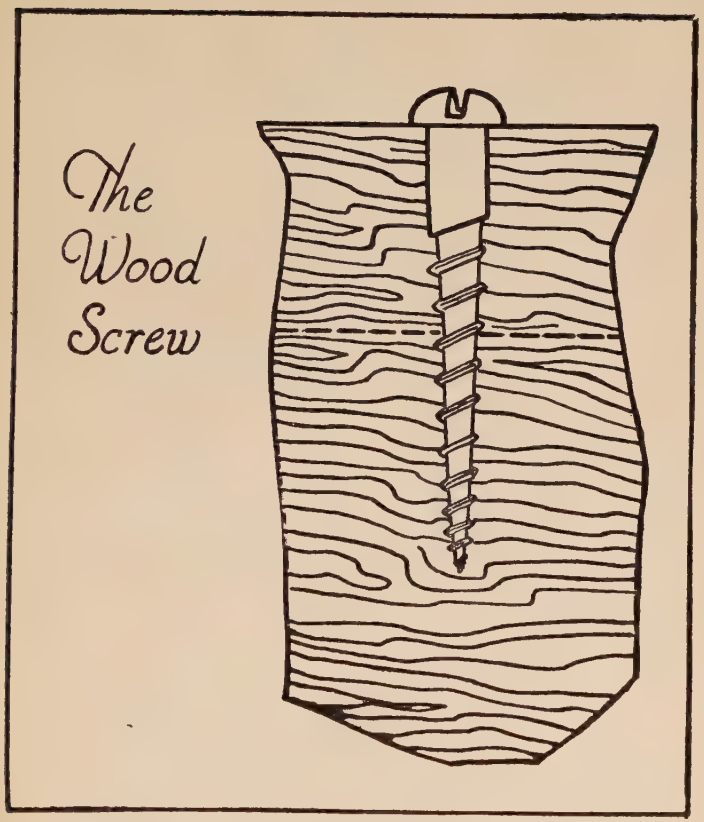


FIGURE 77. The four parts of a wood screw are here shown. Find these in the drawing from the description given in the text.

you turn it into the wood it makes a thread in the wood that just fits the thread of the screw. If you keep on turning a wood screw after the head begins to be tight, the thread acts like the "curly" part of a

bit which tears wood out of a hole. In this way, the fit of the screw in the wood is ruined, and the wooden thread destroyed. Never continue turning the screw after it "comes to a head," as mechanics say. A machine screw is different. It has no worm and cannot cut its own thread. The thread has to be cut for it. It is intended, or course, to be turned into metal. Wood screws are tempered hard and brittle, and therefore they should never be struck with a hammer.

The holding power of a screw is tremendous in proportion to its small size. Here is a good set of rules for using screws, which you ought to study so that you will know the five steps, in what order they come, and how to perform them. Wood screws are used for holding together two pieces of wood; and the way you should treat the first piece is different from the way the second should be treated.

Rules for Using Screws

1. Bore the hole in the first piece of wood. It should be a very little *larger* than the shank of the screw.

2. Countersink this hole if the screw has a flat head, but not if it has a round head.

3. Bore the hole in the second piece. It should be a very little *smaller* than the shank of the screw.

4. Soap the screw. (Do not oil it.) This is best done by scraping the screw across the edge of a cake of soap once or twice.

5. Turn in the screw with a screw driver. The end of the screw driver must not be too big for the slot, or

the head will be injured; nor too small, or the driver will be injured. Stop turning when the screw comes to a head. Never hit a screw with a hammer.

The Wedge

Look at the three samples of wedges in Figure 76. Which one do you think would be the best if you wanted to split a log of wood? Make a wedge of hickory or white oak shaped like Number Three, and split a small block of stove wood with it. The blade of the hatchet or ax is a wedge, and when you strike with it,

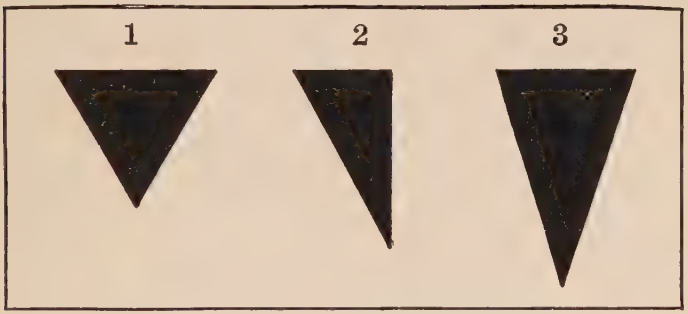


FIGURE 76. Three different kinds of wedges.

you not only cause cutting with the edge, but also splitting with the wedge. If you should draw a dotted line through the middle of Number Three, from the apex to the top, you would see that this wedge is formed of two inclined planes lying back to back.

LIST OF WORDS

lever
axle
pulley
inclined plane

RAILROAD SIGNALS

I. Signals seen.

A. Colors.

1. Red—stop.
2. Green—all clear, go ahead.
3. Yellow—keep on, but look out for signals.
4. Green and white—flag stop.

(By day, these signals are painted semaphores, and by night, colored lights.)

B. Motions: (Made with a flag, a lamp, or simply the hand.)

1. Swung across the track—stop.
2. Raised and lowered—go ahead.
3. Swung in vertical circles—back.

II. Signals heard.

A. Whistles.

1. —— use the brakes.
2. —— —— let off the brakes.
3. —— — — — flagman guard the rear of train.
4. —— —— —— —— flagman come aboard.
5. —— —— —— —— —— same (in another direction).
6. — — the answer to any signal.
7. —— —— —— back.

8. — — — — asking for signals.
9. —— — — watch for signals.
10. —— —— — — coming to a crossing.
11. ———————— coming to a station, whether the train is to stop or not.

B. Compressed air: (Worked by pulling the cord that runs through the train).
1. —— —— go (when the train is standing still).
2. —— —— stop as quickly as possible (when the train is running).
3. —— —— —— back (when standing still).
4. —— —— —— stop at the next station (when the train is running).

This is a list of the signals most commonly heard on the passenger traffic of any railroad. Every child should know most of these, and a good way to learn them is to practice them with a whistle and lantern. Toy stores keep a kind of double-barreled whistle, one barrel shorter than the other, which sells for ten or fifteen cents. You can use this in practicing the whistle signals. If you cannot get a lantern, cut a block of wood six inches by four inches by four inches, and nail to it the bail of an old pail. Even a section of wire alone may be used, but the bail is easier on your hands in swinging the model. Another sort of whistle is a small double tin disc with a hole through the center. This gives a very good imitation of the air valves when they hiss.

Anyone travelling on the railroad often has the following experience: The brakes begin to grind, and the train comes to a standstill where there is no station and no sidetrack. The engineer has seen some signal which read "stop." After a few moments, the passenger hears the whistle blow one long and three short blasts. This is the signal for the flagman to walk back beyond the last car of his train far enough so that there will be plenty of room for another train, approaching from the rear, to stop at his signal. On busy roads, there is always another train not far behind. Presently the passenger hears two short toots from the engine. This is the engineer's reply to some signal—say a signal to go ahead. It may be the swing of a flag or lantern, or some hand-waved signal from a switchman. If the signal to go on is merely the dropping of a semaphore, there will be no reply from the engine.

Now the passenger hears either four or five long toots from the locomotive (the number depending on which direction his train is moving). This is the call to the flagman down the track to come aboard his train. Here there will be a pause when nothing happens—a long pause if the flagman is a long way behind; but short if he has not had time to get far. Then the compressed air cord, that runs the whole length of the train, is pulled, and the valve hisses two blasts. The cord is pulled by the flagman on the back platform of the last car. He is telling the engineer that he is aboard again. If the engineer can see the

flagman quite plainly, this signal may not sound at all; the flagman may simply wave his hand. Then the locomotive gives two short toots, which is the engineer's acknowledgment of the flagman's signal, and the train moves on.

To anyone who knows nothing of railroad signals, all this is very mysterious; but if you have learned something about it, you know just what is happening. Such knowledge adds great fun to any long rail journey.

Listen for signals not given in these lists, and see if you cannot learn some new ones. On the freight traffic, especially, there are many not given here.

One of the best safety devices ever invented is the "block system," which most railroads have installed. Just as a ruler is marked off into inches, so is the track marked off into blocks, or lengths of several miles each. At the beginning of each block is a post with a semaphore. The semaphore can swing up and down, and is moved by electricity running along the rails and through wires in the posts. When a train enters a block the semaphore at the beginning of that block reads danger, and any train coming up behind can see that the train ahead is in that block. The second train must not enter that block until the first train has passed out of it. When the first train passes out, the semaphore falls, showing that the block is clear, and that the second train can go on into it.

BOOK LIST

Should you wish to read other books of science here are some that you will find interesting:

Adams—*Harper's Machinery for Boys*
Bell—*Star-land*
Bert—*First Steps in Scientific Knowledge*
Buckley—*The Fairyland of Science*
Champlin—*The Young Folks' Astronomy*
Collins—*The Boy's Book of Experiments*
Harrington—*About the Weather*
Holden—*The Sciences and Real Things in Nature*
Houston—*The Wonder Book of Magnetism*
Jameson—*The Weather and Weather Instruments*
Jordan—*Science Sketches*
Knox—*All about Engineering*
McFee—*Secrets of the Stars*
Shailer—*The Story of Our Continent*
St. John—*The Study of Elementary Electricity and Magnetism,* and *Things a Boy Should Know about Electricity*
Trafton—*Nature Study and Science*
Washburne—*Common Science*
Winchell—*Sketches of Creation*
Woodhull—Electricity, from *The Children's Library of Work and Play; Homemade Apparatus;* and *Simple Experiments in Physics*

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